International Space Station
Payload Operations Concepts and Architecture Assessment Study

Final Report

Prepared for the

National Aeronautics and Space Administration
Office of Biological and Physical Research

By

Computer Sciences Corporation

Through

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(MOBIS)
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Preface

This report presents the results of the International Space Station (ISS) Payload Operations Concepts and Architecture Assessment Study (POCAAS). The report was prepared by the POCAAS Study Team. Computer Sciences Corporation (CSC) formed the team in response to a Request for Proposal (RFP) from the Office of Biological and Physical Research of the National Aeronautics and Space Administration (NASA).

The Statement of Work for the study required that the Study Team assess the current ISS concept of payload operations and the associated flight/ground architecture for efficiency improvements. The Study Team was also required to recommend the potential for time-phased reductions in the cost of payload operations through efficiency improvements to existing systems, interim or permanent changes to existing requirements on systems, and changes to the current concept of payload operations to take the most effective advantage of continuity in ISS operations. At the first Study Team meeting, NASA charged the Team to focus on alternative concepts, rather than focusing on a detailed audit of current operations.

The Study Team comprised 19 members who were selected to provide a broad knowledge of payload operations in space. The Team members (Exhibit 1) were selected to provide a balance between specific knowledge of current ISS payload operations, experience with prior manned programs (such as Skylab, Space Shuttle, and Spacelab), and experience with unmanned scientific operations (such as the Einstein Observatory, the Hubble Space Telescope, and the Chandra Observatory). The Team included the following individuals:

- Researchers who have conducted experiments onboard the ISS as well as prior manned programs
- Former payload specialists who have flown Space Shuttle and Spacelab scientific missions
- An astronaut who flew on Skylab, as well as Space Shuttle and Spacelab
- Operations personnel who have designed and performed payload operations for both manned and unmanned space programs.

Appendix A contains biographical sketches of all team members.

Exhibit 1. POCAAS Study Team Members

Member Name	Key Background and Experience
Fletcher Kurtz, Study Manager	Director, MSFC Mission Operations Laboratory
John-David Bartoe*	Research Manager, ISS Program; Spacelab Payload Specialist
John Cassanto	Commercial Payload Developer for Shuttle, MIR, and ISS
John Cox	Manager, Space Station Freedom Program
Roger Crouch*	Senior Scientist for ISS, NASA Code M; Spacelab Payload Specialist
Larry DeLucas*	Researcher, Biotechnology; Spacelab Payload Specialist
Dale Fahnestock	Director, GSFC Mission Operations and Data Systems Directorate
Owen Garriott*	Skylab, Shuttle, and Spacelab Mission Specialist

Member Name	Key Background and Experience
Gerald Griffith	Payload Interfaces and Crew Safety, JSC Astronaut Office
Bob Holkan	Manager, Space Station Control Center and ISS Simulator
Chuck Lewis	Chief, MSFC Mission Training Division
Byron Lichtenberg*	Researcher, Life Sciences; Spacelab Payload Specialist
John O'Neill	Director, NASA Space Operations Management Office
Ron Parise*	Data Management Scientist; Spacelab Payload Specialist
Ed Pavelka	Chief, JSC Operations Division
Tom Recio	MSFC Operations Manager, Einstein Observatory and Spacelab
Al Sacco*	Researcher, Materials Science; Spacelab Payload Specialist
Carl Shelley	NASA manned operations and program management; ISS International Partnerships
Jerry Weiler	Chief, MSFC Mission Planning Division

* Prior Payload Specialists

The study was conducted between October 2001 and February 2002. During these four months, the Study Team met in four formal meetings for a total of 10 days; however, much of the Team's work was performed between meetings and coordinated through email and teleconference calls. The Team also formed five subteams to penetrate more deeply into the specific areas of researcher issues, information systems, operations control, planning, and crew support.

The Study Team initially received briefings from NASA personnel regarding the study objectives, the ISS budget, and a payload operations overview. The Team also requested and received NASA briefings on the following:

- Design reference missions to be used in the study
- Each of the four Telescience Support Centers
- Payload Operations Integration Function
- Payload Operations Integration Center
- Changes required to the Space Station Control Center to provide Payload Operations Integration Center (POIC)-equivalent services
- Request-Oriented Scheduling Engine (ROSE)

To validate findings with respect to difficulties currently experienced by researchers in using the ISS, the Study Team addressed a survey to all 61 principal investigators and payload developers currently participating in the ISS Program through Increment 6. Thirty-seven of the survey recipients responded, and their input was extremely valuable.

The Team members, individually and in subteams, also conducted extensive informal discussions with cognizant NASA personnel. The Team appreciates the openness and cooperation of NASA personnel throughout the study. In addition to the leadership and advice of Mark Uhran, the study sponsor, the Team acknowledges, particularly, the following individuals:

Carmine Bailey (Boeing)

Darrell Bailey

Dave Beering (Infinite Global Infrastructure, LLC)
Bob Bradford
Rickey Cissom
Barbara Cobb
Jan Davis
Jerry Geron (TBE)
John Jaap
Mike Kearney
Candace Livingston
Chris Maese
Diane Malarik
Mark McElyea
Ann McNair
Tim Owen
Bob Patterson
Ned Pendley
Lesa Rowe
Julie Sanchez
Doug Sander
Debbie Underwood
Teresa Vanhooser
Lisa Watson

The Executive Summary contains the Study Team's principal findings and recommendations, while supporting analyses and additional specific recommendations are contained in the body of this report. In keeping with the emphasis requested by NASA, the Team focused on the evaluation of alternative concepts and, therefore, did not perform a detailed audit of current payload operations.

Contents

Exhibits

Executive Summary

The Payload Operations Concept and Architecture Assessment Study (POCAAS) for the International Space Station (ISS) was established by NASA's Office of Biological and Physical Research (Code U) to assess the current ISS concept of payload operations and the associated flight/ground architecture for efficiency improvements. The study evaluated the potential for time-phased reductions in the cost of payload operations through efficiency improvements to existing systems, interim or permanent changes to existing requirements on systems, and changes to the current concept of payload operations to take the most effective advantage of continuity in ISS operations.

This Executive Summary presents the Study Team's findings and recommendations. Additional detailed findings and recommendations are contained in the body of the report.

ES-1. The payload operations organization performed admirably during the first year of ISS research under extremely difficult circumstances.

More than 50 investigators have successfully conducted research on the ISS, and more than 50,000 hours of experiment run-time were conducted. This research was performed while the ISS was in the process of major construction, despite significant system anomalies.

A steep on-orbit learning curve was experienced in managing a very complex space facility, which imposed significant requirements and process constraints on the payload operations organization.

ES-2. ISS researchers find the payload integration process, including payload operations, to be unnecessarily and discouragingly difficult.

In comparison to past manned space programs, ISS requirements are too demanding, and enforcement of compliance to these requirements is too strict. There are too many repetitive reviews involving principal investigators (PIs) and payload developers (PDs). Processes are too complicated and inflexible.

Researchers judge the *reflight* of a Space Shuttle or Spacelab payload on ISS to be 2 to 4 times more difficult than the *original flight* on Shuttle/Spacelab. Reflight of an ISS payload on the ISS is not as difficult as the first ISS flight, but significant repetitive work can be reduced.

Recommendation. Reengineer and streamline the payload integration process, including payload operations.

ES-3. Payload operations are a relatively small component of ISS cost.

Of an approximately $2 billion per year ISS Program budget, the ISS research budget of $284 million constitutes 14 percent. Within the research budget, the current $51 million payload operations budget constitutes 18 percent, or 2.6 percent of the entire ISS Program budget.

While the payload operations budget does not appear disproportionate to other ISS Program elements when judged against other comparable space programs, the payload operations cost can be reduced.

Recommendation. Considering the interaction among all payload integration activities, and the researcher issues, reduction in payload operations costs should be undertaken as part of a larger streamlining of ISS payload integration.

ES-4. Payload operations cost can be reduced if a combination of actions is taken.

Program requirements must be modified to allow alternative implementations (e.g., for reflight payloads). Program standards must be modified or interpreted to focus on intent, not rigid adherence (e.g, detailed formatting of crew displays and procedures).

Information exchange requirements among ISS organizations and with researchers must be streamlined to be more effective, less formal, and less redundant.

Operational processes and approval processes must be further simplified.

While some of these actions may be regarded as potentially reducing the efficiency of research resource utilization onboard the ISS, the Study Team believes that this need not be the case. The Study Team believes the increase in researcher satisfaction and reduction in cost greatly outweigh the risk.

Recommendation. Budget reduction should be preceded by a definitive program action, working with the research community, to identify and define specific changes to reduce complexity, increase flexibility, and reduce cost.

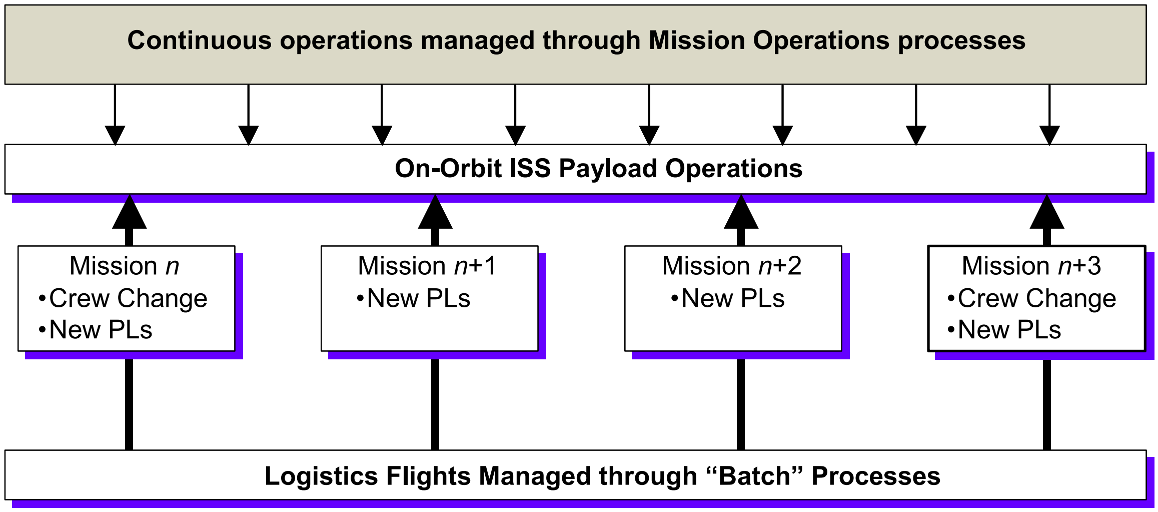
ES-5. ISS operations today are being largely conducted in "sortie" mode; an alternative concept for long-term payload operations is "continuous flow".

In current operations, each Increment (or Expedition) is treated as an entity [planning, preparation, certification of flight readiness (COFR), crew changeout]. New payloads, however, are manifested and certified by Earth-to-orbit-vehicle (ETOV) flight.

The sortie mode of operations was logical, effective, and efficient for early ISS assembly operations. However, as the ISS Program moves toward sustained research operations on-orbit, continuous operations become the objective.

In the alternative concept of *continuous flow* (Exhibit ES-1), the Payload Operations Integration Function (POIF) manages on-orbit ISS payload operations more as a ship at sea. The operations processes currently used by the POIF to manage day-to-day operations during an increment are extended to eliminate the need to recertify payload onboard the ISS and its continuing operation. The POIF has already introduced this mode of operation to some extent in the management of crew procedures and displays. New payloads and payload supplies are logistically provided by ETOV sorties, as is crew exchange.

Exhibit ES-1. Continuous Flow Concept



A comparison of sortie (increment) mode to the continuous flow concept is shown in Exhibit ES-2.

Exhibit ES-2. Comparison of Sortie and Continuous Flow Concepts

Sortie (Increment)	Continuous Flow
• Based on concept that all payloads are "new" for each increment	• Based on concept that majority (75%) of payloads are continuing or reflights from previous ISS operations
• All payload hardware used in an increment must be certified for the increment	• Payload hardware remaining on-orbit was certified when launched (continuing integrity should be periodically reviewed)
• All payload hardware launched on a flight must be certified for the flight	• All payload hardware launched on a flight must be certified for the flight
• Payload crew procedures processed and certified for each increment • Payload displays reviewed and certified for each increment	• Payload procedures and displays established when payload launched and maintained through real-time (RT) operations
• PODF new for each increment	• PODF maintained through on-orbit configuration control
• Crew changeout regarded as beginning of new mission	• Crew changeout regarded as shift handover for ongoing payload operations
• Payload documentation system based on separate documents (or PDL entries) for each increment	• Payload documentation system based on one-time baselining with change control for reflight

Recommendation. Adopt continuous flow processes where possible to reduce repetitious increment-based activities.

ES-6. The current ISS payload operations architecture comprises four primary cost elements.

The four primary cost elements are as follows:

- Payload Operations Integration Function (POIF)
- Payload Operations Integration Center (POIC)
- Telescience Support Centers (TSCs)
- NASA Integrated Services Network (NISN) services

ES-6.1. The POIF provides essential ISS functions.

- Integrating ISS payload operations (U.S. and international partner)
- Facilitating performance of experiments by PIs and crew, and managing shared resources
- Controlling the U.S. payload communications and data handling (C&DH) system, which includes the payload multiplexer-demultiplexer (MDM) system the KuBand communications system, and the onboard communications outage recorders
- Controlling 11 onboard research facilities (8 EXPRESS Racks, MELFI, WORF, and ARIS)

POIF Cost Option 1. The Study Team recognizes that POIF cost was significantly reduced previously through continuous improvement processes that are in place. However, the Team believes that POIF cost can be further reduced through reduction of requirements, reduced rigidity in standards, streamlined processes, and adherence to a minimum service level. The Study Team performed a bottoms-up labor estimate for the POIF assuming incorporation of POCAAS recommendations. The results of this labor estimate are shown in Exhibit ES-3.

Exhibit ES-3. Minimum Service Level Cost Option (LOE/year)

	Current	POCAAS Bottoms-Up Estimate		
Function	**3 Crew, Pre-AC**	**3 Crew, Pre-AC**	**3 Crew, Post-AC**	**6 Crew**
POIF Management	16	7	7	7
Operations Integration – RT	10	9	9	9
Operations Integration – Prep	25	19	20	20
Planning – RT	10	7	8	9
Planning – Prep	30	16	20	21
OC/DMC – RT	28	28	35	35
OC/DMC – Prep	60	36	43	46
Crew Support – RT	9	9	9	9
Crew Support – Prep	53	27	31	55
Total	**241**	**158**	**182**	**211**

Note that the POCAAS estimate was performed separately for three ISS mission phases (three crew, pre-core assembly complete; three crew, post-core assembly complete; and six crew). These phases were defined by the POCAAS in a mission model that reflects the differing numbers and complexity of payloads that can be supported by the ISS and its logistics systems in these phases.

Three other POIF cost options were also evaluated.

POIF Cost Option 2. Delete planned Space Flight Operations Contract (SFOC) instructor support for crew training on payloads. The training would still be performed at the Payload Training Complex (PTC) at Johnson Space Center (JSC) by POIF staff, as it is currently being performed. The Study Team judged that it is more cost effective to focus payload training responsibility within one (POIF) organization.

POIF Cost Option 3. Provide POIF assistance to PIs/PDs above the minimum service level, where the PIs/PDs need and request assistance. This option recognizes that PIs/PDs vary in their experience level with space operations. This is especially true of first-time fliers, while PIs/PDs with prior experience and PIs/PDs supported strongly by Research Project Office (RPO) resources need only the minimum service level.

POIF assistance to inexperienced PDs has reduced development time, reduced overall cost, and resulted in better operations products. This assistance can also allow PIs/PDs to focus on their core competencies of science research and experiment development, while using experienced operations personnel to translate experiment requirements into operations products and formats.

This cost option requires a staff of 10 to 15 operations interface engineers. The precise number should be based yearly on an assessment of the planned payload manifest and, therefore, is expected to change over time.

The operations interface engineers, if maintained in a separate pool within the POIF, can provide an added role of advocacy for continuous improvement within the POIF, by aligning with the perspective of the researchers.

POIF Cost Option 4. Provide additional POIF resources to plan for payload operations with the IPs. Limited process and procedural preparation has been accomplished to date for IP payload operations interfaces.

A dedicated team of 5 or 6 operations personnel is needed in 2003–2004 to develop the IP interfaces and to support an increased level of simulations to validate procedures and train both IP and POIF staff. The precise size of this effort requires further analysis.

Implementation Considerations. The Study Team identified a number of implementation considerations that should be observed if the Team recommendations are accepted.

A balance should be maintained between Federal Government and private-sector (contractor) staffing. The Government component is essential both to exert Government responsibility and to maintain continuity in the core skill base. The current contract for POIF contractor labor is assumed to end in fiscal year (FY) 2004, due to expiration of the current NASA 50000 contract late in that year.

Capability should also be retained to rotate POIF staff between on-console real-time shifts and preparation work performed in the normal office work environment. This rotation is essential for retaining both staff and skills.

A phase-in of the POCAAS minimum service level model is required to accomplish changes in current requirements, documentation, and operating practices, and to avoid disruption to ongoing payload operations. Exhibit ES-4 shows a recommended phase-in profile. The profile reflects a transition in FY 2002–2003 to the minimum service level model. A transition from the three-crew, pre-core assembly complete payload traffic model (30 payloads/increment) to the higher three-crew, post-core assembly complete payload traffic model (40 payloads/increment) begins in FY 2005, based on the POCAAS mission model. Although IP payload operations may begin in FY 2005, the total payload workload does not change until FY 2006. The additional initial effort required for integration of the IPs into payload operations is separately accounted for in Option 4. The transition to the six-crew payload traffic model (70 payloads/increment) begins in FY 2008.

Exhibit ES-4. LOE Phasing for POIF Cost Options

FY	02	03	04	05	06	07	08	09	10	11
Cost Option 1										
Government	66	58	50	50	50	50	50	50	50	50
Contractor	175	142	108	120	132	132	147	161	161	161
Cost Option 3										
Contractor		15	15	15	15	15	15	15	15	15
Cost Option 4										
Contractor		5	5							
Total	**241**	**220**	**178**	**185**	**197**	**197**	**212**	**226**	**226**	**226**

The assumed Federal Government staff level in FY 2003 and subsequent is an arbitrary fraction of the total staff.

POIF Recommendations.

POIF Cost Option 1 — Minimum Service Level. The Study Team recommends that this option be adopted, with an appropriate phase-in, and conditional upon similar ISS Program changes in payload integration that are necessary for success of the option.

POIF Cost Option 2 — Elimination of SFOC Training Instructors. The Study Team recommends adopting this option. A level of SFOC funding must still be maintained to support PTC maintenance.

POIF Cost Option 3 — PI/PD Assistance. The Study Team recommends that this option be adopted, subject to a review of the planned payload manifest and the needs of manifested PIs/PDs.

POIF Cost Option 4 — IP Operations Preparation. The Study Team recommends reviewing this option with respect to IP agreements, processes, and timing. Timely preparations for IP payload operations are essential to avoid disruption and loss of science return.

ES-6.2. The POIC provides the essential core information technology infrastructure necessary to conduct payload operations.

The POIC performs the following functions:

- Real-time (RT) and near-real-time (NRT) telemetry processing

- Command processing
- POIC and remote command and display processing
- KuBand data distribution via the Payload Data Service System (PDSS) to the Internet
- Local and remote voice communications (HVoDS/IVoDS)
- Local video distribution
- Operations tools hosting

POIC development was completed within the past year, and a final major software delivery is scheduled for the second quarter of CY 2002. As development tasks were completed, the POIC contractor staff was reduced from 250 in March 2001 to a planned 125 in March 2002. Systems of this type typically require approximately 1 year to stabilize operation after completion of development.

The POIC systems, as designed and implemented, are highly capable, highly distributed, and relatively complex to operate. The Study Team found that technology refreshment is essential to reducing the cost of operating the POIC, as well as to maintain system effectiveness:

- Some POIC equipment is nearing end-of-life or economical operation
- Newer technology allows system consolidation and lower maintenance or operating cost
- Simplification and increased automation of operations, arising in part from newer technology, is essential to reduce labor cost
- Technology refreshment requires investment for reengineering hardware and software, and for acquiring new technology hardware

POIC technology refreshment should include the following:

- Performance of reengineering in FY 2002–2004 directed at cost reduction
- Consolidation of servers, with consideration of leasing operational servers beginning in FY 2004 and refreshing them at 3-year intervals thereafter
- Provision of sufficient robustness and reserve capacity to allow maintenance on an 8-hours-per day, 5-days-a-week nominal basis
- Completion of the ongoing transition from workstations to PCs for command and display functions
- Porting of the Payload Planning System (PPS) software to the IBM platform used for the Crew Planning System (CPS), and elimination of the current DEC platform
- Increased automation of configuration and reconfiguration control

These changes should allow the reduction of sustaining engineering and operations staffs in FY 2005 and subsequent by approximately 20 percent, in addition to substantial reduction in license and hardware maintenance costs.

Recommendation. Reengineer the POIC to reduce cost. Make a $6 million investment over the FY 2002–2004 time period above FY 2002 budget guidelines, and reduce the operating budget in FY 2005–2011, achieving a reduction of $36 million (18 percent) from the FY 2002 budget level over the 10-year period FY02–2011.

ES-6.3. The four Telescience Support Centers (ARC, GRC, JSC, and MSFC) are multifunction but research discipline-focused facilities.

- Real-time operations integration and control of ISS discipline-dedicated, facility-class racks
- Provision of remote operations resources for PIs/PDs located near the TSC
- Other synergistic Research Program Office (RPO) activities that vary by TSC

The Ames Research Center (ARC) TSC is designed around the operation of space biology payloads that include animal habitats and animal experimentation. These payloads require extensive ground control experiments in parallel with the flight experiments, and extensive prelaunch support to activities at the launch site. However, this class of experiment is a heavy user of crew time and is, therefore, expected to be curtailed during the three-crew mission phases. The ARC TSC also supports the Avian Development Facility (ADF) and the Biomass Production System (BPS) experiments.

The Glenn Research Center (GRC) TSC is designed around the integration of experiments using the Fluids Integrated Rack (FIR) and the Combustion Integrated Rack (CIR). However, the FIR and CIR are not scheduled for launch until CY 2005. Their operation, originally planned for use with multiple payload inserts per increment, is now expected to involve only one payload insert per increment during the three-crew mission phase. The GRC TSC also currently supports the Space Acceleration Measurement System (SAMS) payload.

The Johnson Space Center (JSC) TSC is designed around the integration of experiments using the Human Research Facility (HRF), which is currently in operation. Additionally, the JSC TSC supports other biotechnology experiments [currently Biotechnology Specimen Temperature (BST) and Biotechnology Research (BTR)], Active Rack Isolation System ISS Characterization Experiment (ARIS-ICE), Earth observations, and EARTHKAM.

The Marshal Space Flight Center (MSFC) TSC supports Material Science Glovebox (MSG) and Biotechnology Glovebox facilities, as well as Protein Crystal Growth payloads.

Recommendation. Transfer TSC budgets from payload operations to the respective RPOs, and treat the TSCs as science discipline facilities rather than common-use payload operations facilities. Their costs should be justified on the basis of the payloads they support, and judged relative to the cost of equivalent remote PI services. (Code U had already taken this action prior to the POCAAS). The RPOs should consider deferral of ARC and GRC capabilities (and costs) until those facilities are needed for facility rack support.

ES-6.4. NISN costs and increasing budget trends are counter to current commercial costs and trends.

The NISN budget for ISS payload operations services shows an increase of 10 percent per year through FY 2006. However, the budgeted NISN costs are more than twice the current cost for equivalent commercial services, and commercial long-line costs are decreasing at a rate of 40 percent per year.

Recommendation. Pursue alternative means of providing communications services at lower cost.

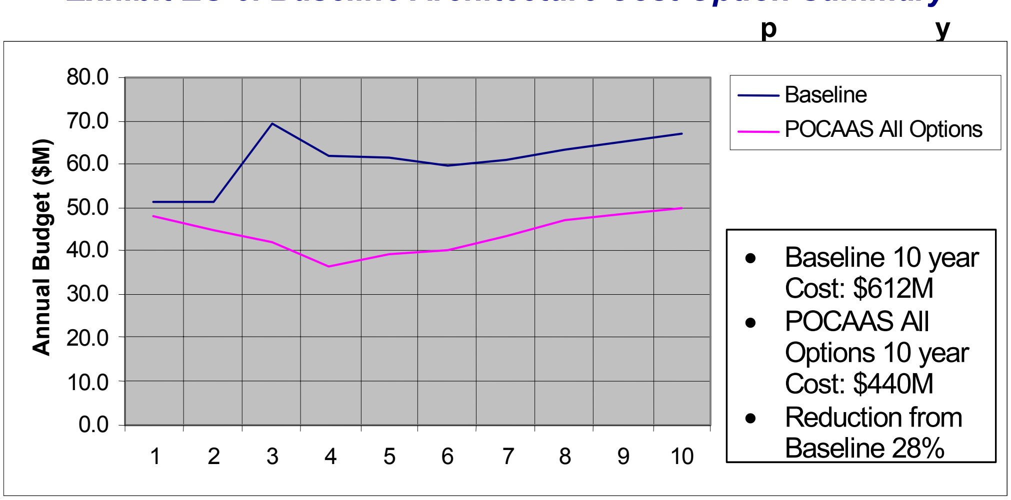
Recommendation. Defer the requirement for distribution of ISS onboard video to the TSCs and RPIs (approximately $780,000 per year). (This recommendation does not affect experiments with video data embedded in the experiment data stream.) Any experiments needing ISS video in their operations should be evaluated on a case-by-case basis, and less expensive means of video transmission sought. For example, NASA TV has been used in the past for this purpose.

Recommendation. Defer the requirement for an increase in the current 50Mb/sec KuBand communications rate until a justified payload requirement is defined, which would remove $24.9 million from the FY 2004–2006 budget. Evaluate alternative implementation alternatives that are available at less cost to meet any defined requirement.

ES-6.5. The POCAAS options identified above result in a 28 to 32 percent reduction in the FY 2002–2011 payload operations costs.

Exhibit ES-5 illustrates the cost reduction over time. The options included assume an integrated ISS Program reduction in requirements and documentation imposed on payload integration and operation. The cost shown includes all payload operations budget items (POIF, POIC, PTC, TSCs, NISN, and PPS) and all POCAAS-recommended options.

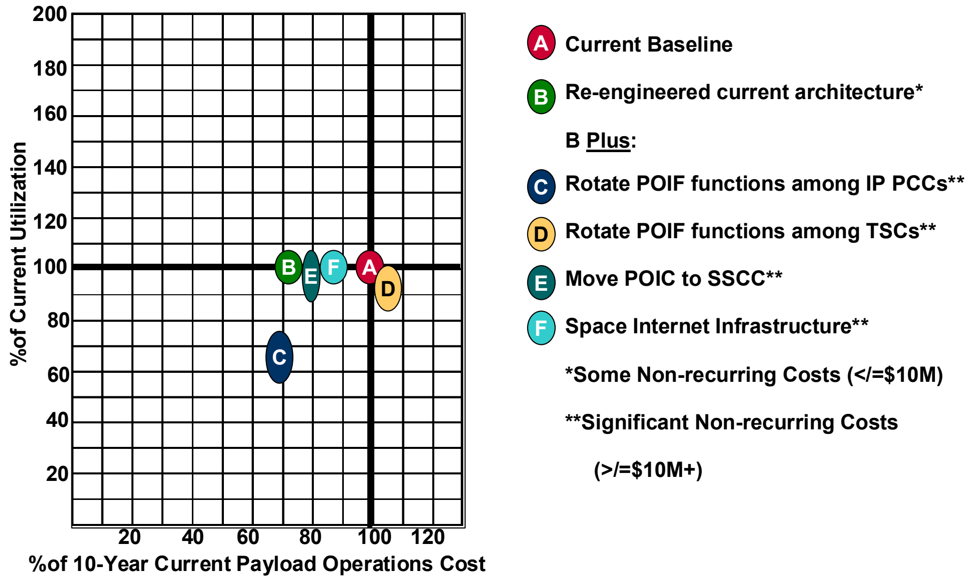
Exhibit ES-5. Baseline Architecture Cost Option Summary



ES-7. The Study Team considered a variety of alternative payload operations architectures, and evaluated six alternatives that encompass other variants.

A notional evaluation of the 10-year cost and research resource utilization of the six architecture alternatives considered is shown in Exhibit ES-6. Other evaluation factors were also separately considered.

Exhibit ES-6. Notational Research/Cost Evaluation of Alternative Architectures



The Study Team found that while the current architecture is sound, reengineering requirements, processes, and functions, as described previously in Section ES-6, can significantly reduce cost.

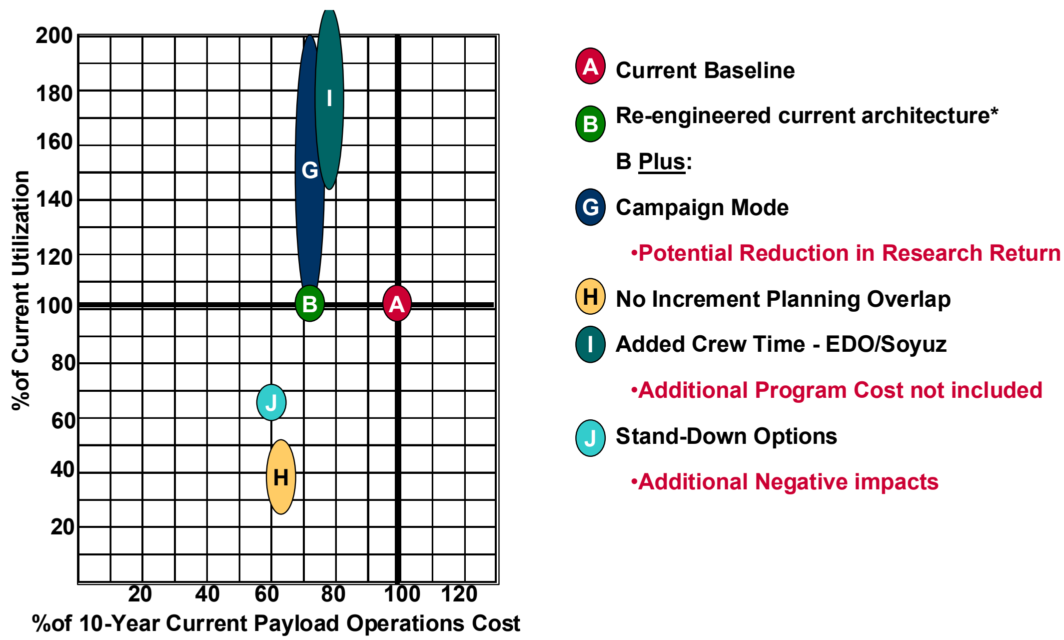
The alternative architectures studied have higher recurring costs than the reengineered current architecture, and each alternative has additional operating disadvantages. The alternative architectures have large nonrecurring costs associated with their implementation. None of the alternatives was found to have a strong technical advantage over the current architecture.

Recommendation. Reengineer the current payload operations architecture. The Study Team recommends against the alternate architectures studied.

ES-8. The Study Team evaluated a variety of alternate mission concepts and recommends two for consideration.

A notional evaluation of the 10-year cost and research resource utilization of the six mission concept alternatives considered is shown in Exhibit ES-7. Other evaluation factors were considered separately.

Exhibit ES-7. Notational Research/Cost Evaluation of Alternative Mission Concepts



In the campaign mode, the analysis assumed that one discipline was given overriding priority in assignment of resources available to payloads during an increment. Resources available in excess of the discipline requirements were then allocated to other disciplines. Each of the three major discipline areas (life sciences, microgravity sciences, and commercial applications) was given priority on an increment, in sequence.

Use of the full campaign mode increases overall resource utilization but has potential negative effects on research requiring frequent and continuing access to ISS. This situation occurs because only limited or no resources are available to the nonpriority disciplines on two of three increments.

However, the analysis suggests that partial campaign mode strategies, in which resource priorities are set over shorter time periods than an increment, or the priority discipline is given less than total priority, offer increased resource utilization while avoiding the negative effects on research.

Recommendation. The program should continue to evaluate campaign mode variants to maximize research achievements.

The Study Team believes that increased crew time for payloads is essential to realizing the research objectives of the ISS. Access of career researchers to ISS, either as part of the career astronaut corps or as payload specialists from the research community, is also essential to realizing the research objectives of the ISS.

Recommendation. The ISS Program should pursue increased research crew time, including extended duration orbiter (EDO)/Soyuz options, as possible within funding constraints.

ES-9. Recommended Summary Action Plan

1. Establish a standing ISS Program Research Operations Council, comprising experienced NASA researchers and senior NASA managers, with authority to oversee efforts to enhance research operations and reduce cost.
2. Formulate and annunciate a Program policy directed toward increasing flexibility in requirements, standards, and processes, with the goal of enhancing research, reducing cost of integration and operations associated with research, and increasing customer (i.e., researcher) satisfaction.
3. Develop a plan for evolution of research operations, and establish accountability for the accomplishment of the plan.
4. Conduct an audit of payload integration and operations requirements, with participation of experienced researchers.
5. Review information exchange requirements among researchers and Program elements, with a focus on eliminating duplication of inputs, reducing workload, and fostering communications.
6. Review payload integration and operations processes with the objective of simplification and workload reduction.
7. Move toward the concept of continuous operations.

Section 1. Introduction

1.1 Study Background

To understand the objectives and the results of the Payload Operations Concepts and Architecture Assessment Study (POCAAS), some background on the International Space Station (ISS) Program in general and ISS payload operations in particular is needed.

1.1.1 International Space Station Program

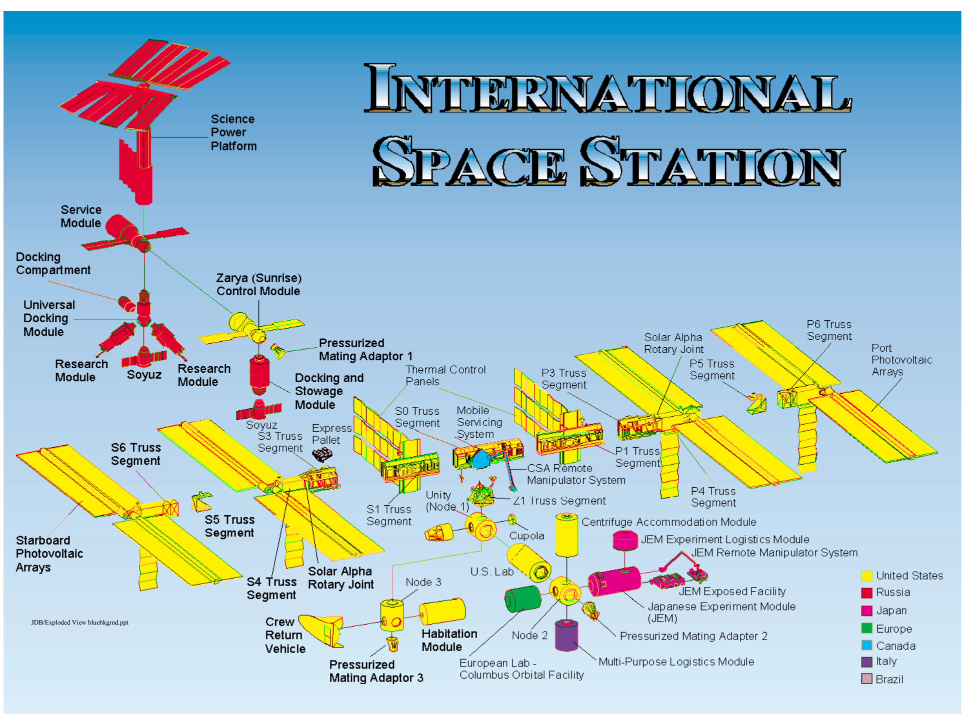
The ISS is intended to provide a quantum leap in the world's ability to conduct research on orbit. It serves as a laboratory for exploring basic research questions in commercial, science, and engineering research disciplines and is a testbed and springboard for exploration.

Key features of the ISS Program that affect payload operations include the ISS configuration, the international partnerships (IPs), and the ISS research objectives and allocations.

1.1.1.2 ISS Configuration and Operations

The ISS, when fully assembled, will consist of pressurized elements provided by the U.S., the European Space Agency (ESA), the National Space Development Agency of Japan (NASDA), and Russia, as well as other elements mounted on an external truss structure. Exhibit 1-1 illustrates the ISS intended configuration.

Exhibit 1-1. Expanded View of ISS Elements Color Coded by Provider



The truss structure supports solar arrays for power, cooling arrays for thermal control, payloads mounted on pallets, and antennas for communications with the Tracking and Data Relay Satellite System (TDRSS). When completed, the ISS will house seven crew members from different nations in a habitation and laboratory complex with a mass of more than 450,000 kilograms (1 million pounds) and a volume of 1,220 cubic meters (43,000 cubic feet) at sea-level atmospheric pressure.

The initial configuration provides living accommodations for three crew-persons, and a Soyuz capsule for emergency escape to Earth. The plan is to add living accommodations for an additional three or four crew-persons (total of six or seven) and to provide a crew rescue vehicle (CRV) capable of carrying the maximum crew back to Earth.

The number and complexity of the ISS systems require a significant amount of crew time for maintenance and operation, independent of any payload (research) operations.

Because the ISS is a manned space habitat, its operation involves significant logistics activities. These activities include transport of crew, experiments, and supplies to and from the ISS. Transport is provided by periodic launches of the Space Shuttle, by Russian manned and unmanned vehicles, and eventually by unmanned ESA and NASDA vehicles.

ISS operations are planned against increments and missions. An increments is the period of time that one specific crew complement remains on the ISS. Although originally planned to be 3 months long, increments are currently about 5 months long, and 6-month increments are being discussed. Missions are the activities associated with a particular transport launch to the ISS. Payload equipment delivery and return are keyed to missions.

1.1.1.3 International Partners

The ISS is truly an international endeavor. Although the U.S. has led ISS development, seven countries have contributed to its development. Each partner's responsibilities and rights are spelled out through a multilateral International Government Agreement and through bilateral Memoranda of Understanding (MOUs), which have the binding effect of contracts among the sponsor countries.

Among the rights allocated to each partner is a share in the research to be conducted on the ISS within the U.S, ESA, and NASDA elements. Each partner's share is characterized by a portion of the ISS resources that are available for research (e.g., volume, mass, power, cooling, and data).

Russia does not share within the U.S., ESA, and NASDA elements, but has full rights to conduct research within the elements that it provides.

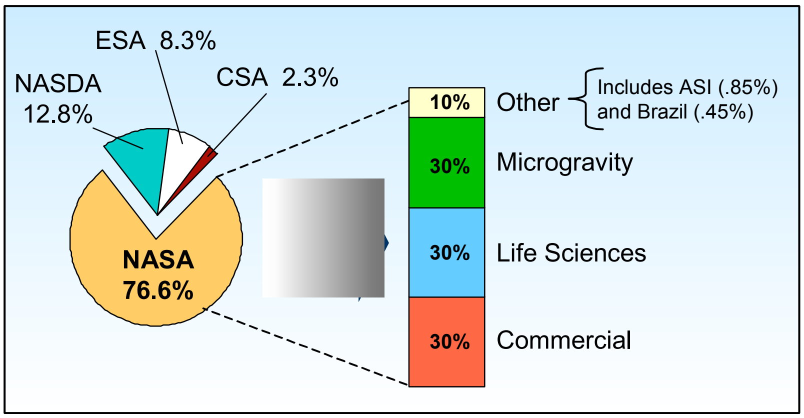
1.1.1.4 ISS Research

The ISS has already begun to fulfill its role as the premier world-class research facility in space. Experiments have been and are currently being supported. As it reaches its full potential, the ISS will support research in the areas of science, technology, and commercial endeavor that can benefit from a continuous microgravity, vacuum, and low-Earth-orbit environment.

Under the MOUs, the basic U.S. and IP research allocations are as shown in Exhibit 1-2. These allocations are further subject to various barter agreements among the partners. Additionally, the Space Station Utilization Board has established that the U.S. pressurized allocations within the pressurized modules will be suballocated as shown in Exhibit 1-1. These allocations are intended to be achieved over a reasonable period of time—not on a day-by-day, or even increment-by-increment basis.

Payload operations on the ISS were begun with Increment 0 in September 2000; three experiments were conducted during that increment. Payload operations are continuing in parallel with ongoing ISS assembly operations, although limited to the amount of ISS resources (crew time, upmass, power, etc.) available after ISS assembly and maintenance activities are scheduled.

Exhibit 1-2. Pressurized Resource Allocation



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The maximum utilization of the research potential of the ISS will be a function of how well the ISS capabilities (and the access to those capabilities) serve the research and commercial communities. Critical aspects of research accommodation are the process complexities and costs involved in conducting experimentation on ISS, and the user-friendliness or transparency and affordability of the processes. This study was initiated to address those issues as related to the payload operations segments of the overall payload integration and execution process.

1.1.2 ISS Program Status and Issues Affecting the Study

In the Spring of 2001, NASA (together with the new U.S. Administration) began to address significant budget problems associated with the ISS. NASA chartered the ISS Management and Cost Evaluation (IMCE) Task Force to address the completion of the ISS assembly within terms of reference established jointly by NASA and the Office of Management and Budget (OMB). The IMCE Task Force Report (from NASA Website) reaffirmed that the fundamental purposes of the ISS remain…

> …scientific research and international cooperation. Specific objectives are:
>
> To provide the means to sustain humans during extended space flight. This will require a primary research focus on discovering any adverse effects of long-term human presence in space.
> Perform "world-class" scientific research that requires low gravity and is enhanced by astronaut interaction.
> Enhance international cooperation and U.S. leadership through international development and operations of ISS.

However, an OMB action to contain the ISS Program overrun reduced the ISS research budget from \$500 million to \$300 million. As part of the effort to achieve the ISS research objectives within budget constraints, NASA issued the RFP for the POCAAS study in September 2001.

The following ISS Program issues are associated with the budget overrun and affect payload operations:

- Availability and timing of ISS capability to increase the crew size from three to six
- Potential violation of the IP MOUs, and the effect of violation on ISS assembly schedule and operations
- Timing and configuration of core assembly complete
- Number of U.S. payloads supported by ISS resources and by the research budget
- Number of Space Shuttle launches per year, and its effect on payload manifesting
- Duration of increments and the frequency of missions

1.1.3 Payload Operations

Payload operations are defined as the activities necessary during real-time operations to support both researchers and the ISS crew in performing research onboard the ISS and the preparation activities necessary to accomplish real-time operations. They include the personnel and information technology infrastructure necessary to define and schedule operations to be performed; train the crew; operate ISS equipment supporting the experiments; support the crew on-orbit; command experiments from the ground; and achieve data and sample return to Earth. More definitive definition is provided in Section 3 of this report.

Payload operations are distinct from other program functions necessary to enable research onboard the ISS. Other payload-related program functions include the following:

- Designing and developing both experiment equipment and the supporting flight systems to perform research.
- Manifesting payload equipment and samples on transport vehicles to and from the ISS. Payload manifesting is constrained by available transport space and mass, after transport of supplies necessary for assembly and sustainment of the ISS and its crew.
- Performing analytical integration to determine the compatibility of payload design with ISS and its transport systems. Analytical integration is performed through a variety of engineering analyses.
- Conducting physical integration of experiment flight equipment and supporting equipment with their transport carriers.
- Managing the safety review process to ensure that experiment flight hardware does not cause any hazard to the ISS, its transport vehicles, and personnel or to ensure any potential hazards are safely controlled.

1.2 Objectives and Approach for the Study

The objectives of the study are summarized in below and defined more completely in the Statement of Work (SOW) (see Appendix A):

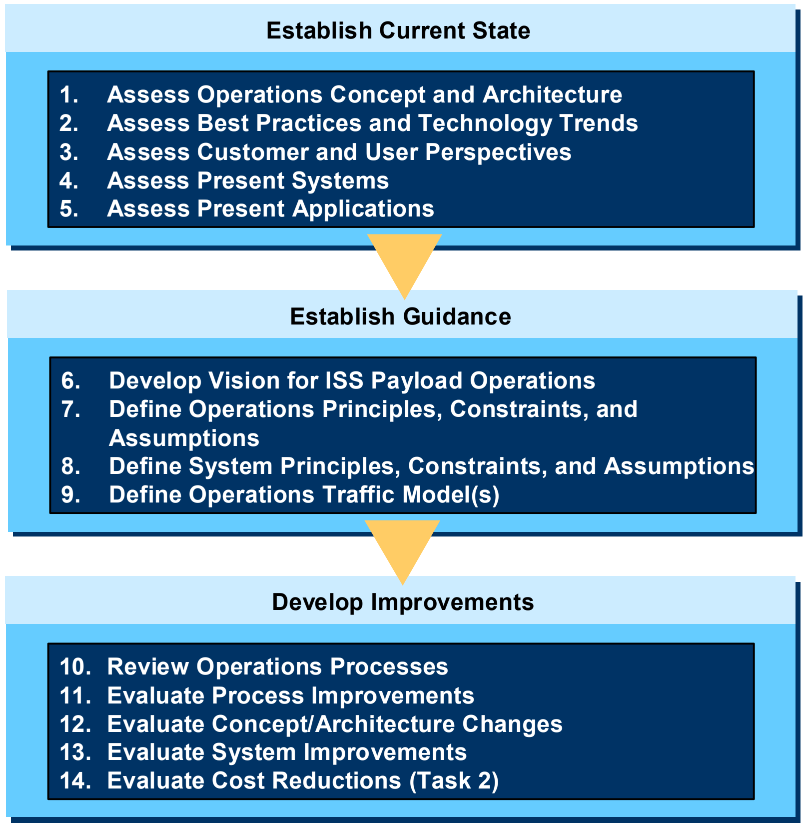
- **Task 1.** The contractor will assess the current ISS concept of payload operations and the associated flight/ground architecture for efficiency improvements.
- **Task 2.** The contractor will recommend the potential for time-phased reductions in the cost of payload operations through the following approaches:
  - Efficiency improvements to existing systems
  - Interim or permanent changes to existing requirements on systems
  - Changes to the current concept of payload operations to take the most effective advantage of continuity in ISS operations.

Study guidance received from NASA place emphasis on changes to operations concepts that would result in significant simplification and cost reduction, as opposed to a detailed audit of current operations procedures. NASA guidance also directed that the study effort be confined to payload operations, although it was recognized that other program elements (e.g., manifesting, analytical integration) that strongly interact with payload operations are of equal importance to research success and cost.

The Study Team adhered to the objectives and guidance, but with the cognizance that the final success of the ISS lies in the research that it enables. Therefore, the Team has also given attention in the study to the need for payload operations to support effective research and to pursue the goal of making research onboard the ISS easier and more effective from the researcher's perspective, as well as making the payload operations for that research less expensive.

With these objectives in mind, the Study Team followed an adaptation of Computer Science Corporation's (CSC's) Business Area Architecture Methodology (Exhibit 1-3) to conduct the study.

Exhibit 1-3. Business Area Architecture Process



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Based on the Team's understanding of the ISS Program objectives, the Team formulated its Payload operations vision and principles, which are presented in Section 2 of this report. Section 2 also includes an assessment of current ISS practices from a researcher's perspective, based both on the experience of Team members and a survey of other current ISS researchers. The researchers' assessment identifies issues with current ISS Program practices, not limited to payload operations, that need to be addressed. As such, the Study Team has attempted to address these issues, as they pertain to payload operations, in these recommendations.

In understanding current ISS payload operations, the Study Team established with the ISS Program Office a budgetary, mission, and current operations architecture baseline for the study. Because the program is currently in a state of flux pending resolution of larger budget issues, the baseline established for the study was essential to the quantification of cost results. While the qualitative findings of the Study Team are largely independent of the baseline, cost is a function of the specific mission requirements imposed upon payload operations. The program baseline is presented in Section 3.

Section 4 presents the Study Team's analysis of the current payload operations architecture against the vision and the mission requirements. Each element of the current architecture is described and analyzed, and findings are presented, which include observations, cost options, and recommendations.

Section 5 presents alternative payload operations architectures and mission concepts that might be used for ISS payload operations.

Section 6 specifically addresses the SOW requirement for recommended interim and permanent changes to current NASA user development requirements. These are actions that research teams might take to reduce payload operations costs.

Section 7 responds specifically to the SOW requirement for recommendations on changes to the ISS concept of operations, which take full advantage of the continuous operations environment afforded by the ISS. This section delineates operational characteristics of the ISS as opposed to other programs and addresses how those characteristics affect operations. The findings in this discussion have been incorporated into Sections 4 and 5, but are focused in Section 7 on the perspective of the continuous operations environment provided by long-term manned operations in space.

Section 2. Payload Operations Vision and Principles

This Section discusses the Study Team's vision for ISS payload operations, first-principles guiding the implementation of the vision, and other basic payload operations concepts. Also included is an assessment of current ISS practices from a researcher's perspective, based both on the experience of Team members and a survey of other current ISS researchers. Their assessment identifies issues with current ISS Program practices, not limited to payload operations, that need to be addressed. The Study Team has attempted to address these issues, as they pertain to payload operations, in the recommendations of the study.

2.1 Payload Operations Vision

The Team's vision of ISS payload operations is as follows:

- To facilitate the pursuit of flight research and make the complex operating environment associated with the ISS transparent to the end-user
- To make the researcher fully responsible for the success of his/her experiment, and to enable the researcher to interact with his/her experiment apparatus, as nearly as possible, in the same way he/she would interact in a remote Earth laboratory.
- To provide the integrated operations services necessary to facilitate the researcher's conduct of science at the minimum possible cost, consistent with the objectives of maintaining crew and ISS safety, and protecting each payload from damage or interference from other payloads.

2.2 Payload Operations Principles

The fundamental principle for research operations is that the PIs, supported by their scientific and payload developer teams, are responsible for conducting and executing experiment operations, insofar as possible. The PI may delegate certain functions to the flight crew, or to other payload operations personnel, who may be required to exercise judgment in execution of their defined functions. However, both the crew and ground operations personnel are obligated to operate within guidelines, procedures, and training provided by the PI.

With this fundamental principle in mind, payload operations staff and infrastructure exist to

- Provide an operations environment where the researcher can achieve mission success.
- While
  - Ensuring the safety of crew and ISS
  - Avoiding damage to one payload as a result of operation of another
  - Avoiding interference among operation of experiments
  - Satisfying programmatic requirements, including international agreements on resource distribution

- Operate Payload Support Systems (PLSS) and Laboratory Support Equipment.
- Support the Flight Crew, both in operations of payloads and PLSS.

The term *PLSS* is used here to include a variety of supporting equipment, including such items as payload racks and their power, cooling, and data subsystems; payload facility equipment; and payload subsystems for acquiring, transmitting, and distributing data. A more complete definition of PLSS equipment is provided in Section 3, as part of the mission requirements.

2.3 Payload Operations Concepts

2.3.1 ISS as a Research Facility

ISS payload operations processes and systems should be designed first and foremost to support the use of the ISS as a research facility.

The Study Team believes that world-class research demands that payloads be flown with a minimum of delay and a freedom to try new ideas and approaches.

The Study Team recognizes that a new program such as ISS should begin with proven concepts and experience, and ISS payload operations were built on the experience gained from the Skylab, Space Shuttle, Spacelab, and MIR programs. However, the ISS environment is different in many ways from that of previous programs, and better ways of operating that are adapted to the ISS environment must be developed to achieve the vision.

Also, many flight and ground systems were designed and baselined 6 to 7 years ago. The ISS Program must include the capability to update these designs over time, so as to take advantage of new technology that will enable world-class research.

In reviewing current operations processes, the Team reached the conclusion that present processes are too lengthy, costly, and overly constraining for scientific purposes. Ralph Larsen, Chief Executive Officer of Johnson and Johnson (a leading pharmaceutical company), recently said “Bureaucracy is the enemy of research.” The Study Team believes that the ISS Program must streamline its processes to enable the vision.

2.3.2 Payload Operations as One Component

Payload operations is only one of many components necessary to enable world-class research onboard the ISS.

While the scope of POCAAS is limited to an analysis of payload operations, the POCAAS Team recognizes that payload operations alone cannot achieve the vision of the ISS as a research laboratory. While payload operations must be streamlined to facilitate research, those operations must be streamlined in consonance with the streamlining of other ISS Program activities.

2.3.3 Dynamic Change as a Way of Life

ISS payload operations should adopt dynamic change as a way of life. The dynamic change taking place in science and technology dictates that ISS payload operations should be under continuing review for new and better ways to do business.

The changing needs of the research community should be continually sought and incorporated as practical into ISS payload operations. World-class research in the year 2010 will not be conducted as it was in 1990, nor as it is in 2002.

For example, the Study Team believes that new commercial standard communications technology should continue to be introduced into the ISS Program over time, to facilitate a more transparent interface between scientific investigators on the ground and their experiments in space. ISS payload operations is a pioneer in the application of Internet technology to facilitate distributed payload operations. This initiative should be continued so as to take advantage of increasing Internet capabilities and should be extended to the space segment of communications. (This topic is discussed further in Section 5.1., Option.)

2.3.4 Recommendation for Research Operations Panel

The Study Team recommends that NASA should establish a broad-based research panel, or other means, to identify operational needs and concepts that will facilitate world-class research. This mechanism should perform on a continuing basis, as the ISS itself, the ISS research program, and technology evolve.

This study was focused by our SOW on the NASA payload operations activities and costs necessary to support ISS science operations during the assembly and early operations years. However, a long-term perspective is also needed to guide the evolution of processes and systems. This perspective should be established in conjunction with the definition of the ISS Research Program, as called for the IMCE Report.

2.4 Current Researcher Issues: The Reality of Current ISS Practices

The active researchers on the POCAAS Team identified a number of key issues that they believe are causing unnecessary cost for ISS research and are inhibiting researchers who would potentially use the ISS as a research facility:

- Current ISS payload practices (not confined to payload operations) are resulting in a documentation burden on the PIs that is significantly greater than for Spacelab or other past human space missions
- The ISS Payload Data Library (PDL) requires excessive researcher effort to maintain and is not always used by the NASA payload operations personnel
- ISS payload operations planning and execution practices enforce adherence to standards and programmatic requirements to unnecessary degree
- ISS payload operations planning and execution practices are overly formalized with multiple approval levels
- Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily

2.4.1 Researcher Issue Validation Survey

To validate these issues in the larger community of ISS researchers, the Study Team sent a brief questionnaire to test the validity of these issues. The questionnaire was sent by email to all 61 PIs and PDs currently participating in the ISS Program through Increment 6. A copy of the questionnaire and the list of addressees are provided in Appendix C.

The questionnaire requested the respondents to indicate their disagreement or agreement with the key issues listed above, according to the following scale:

0 = Insufficient direct knowledge or experience on which to base a response

1 = Strongly Disagree

2 = Somewhat Disagree

3 = Somewhat Agree

4 = Strongly Agree

The scale was developed to provide a forced-choice response set, while allowing for the possibility that the respondent might judge they had insufficient knowledge to respond to a particular question. Respondents were additionally invited to provide comments or recommendations for each issue and were assured that their responses would be kept confidential as to source.

Prior to sending out the questionnaire and in some of the responses, the Study Team recognized that the issues were negatively cast. As such, the Team considered alternate approaches. However, the purpose of the questionnaire was to validate or invalidate the issues previously identified within the Study Team, and the Team chose not to create a more general survey. Therefore, in the background and instructions section of the questionnaire, we acknowledged the negative wording, called it to the attention of the respondents, and asked them not to be influenced by the formulation of the questions.

Dr. John-David Bartoe, NASA ISS Research Manager, served as the named point of contact. The questionnaires were sent in his name and responses were returned to him.

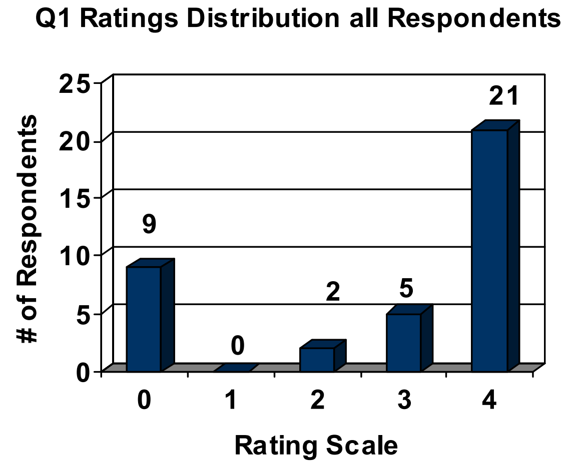
2.4.2 Survey Response

Thirty-seven responses were received from 18 PIs, 11 PDs, and 8 who were both PIs and PDs; the response rate of 61 percent (37 of 61) was better than expected for surveys of this type. The principle conclusion was that the ISS researcher community validated all five issues. The overall rating of agreement for the entire set of issues was 3.4, well exceeding the rating of 3 (somewhat agree), and each individual issue comfortably sustained an average rating on the "agree" side of the scale. The average range of agreement per question was from a low of 3.3 to a high of 3.7.

In addition to the scores, the high volume (96) and intensity of the voluntary written comments confirmed the key issues identified by the Study Team.

The scoring for each individual issue is summarized below together with a few sample comments. A detailed statistical analysis of the responses is given in Appendix C. A complete listing of comments is also provided in Appendix C. Because of the design characteristics of the survey, the results should be considered as indicative of trends and "pointers" to areas and topics requiring further explanation and clarification.

Question/Issue 1: Current ISS payload practices (not confined to payload operations) are resulting in a documentation burden on the Principle Investigators that is significantly greater than for Spacelab or other past human space missions.



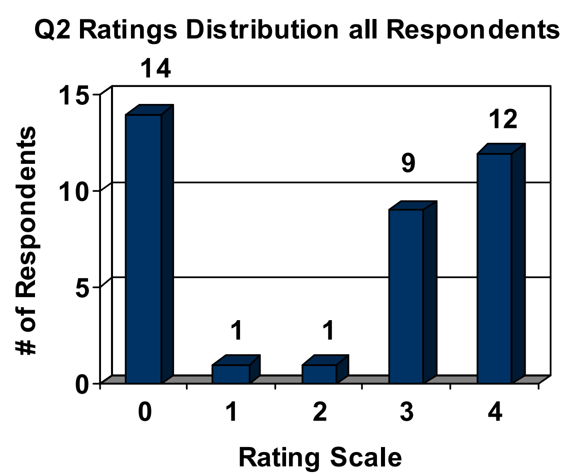
The mean score was 3.7, indicating a strong level of agreement among the respondents. Some written comments were as follows:

- "Compared with Shuttle/MIR the computer software design process, training approval process, differing standards at JSC and MSFC, competing committee structures, changing requirements…are more cumbersome and frustrating."
- "Major factor regarding burden is that NASA does not have a coordinator and there are a hundred people asking for information …."
- "…it is also significantly greater than for middeck payload….ISS….requirements can be trimmed."
- "I have been developing and successfully flying experiments since 1974 and have never seen it this bad or as confusing as it is…We should do business the way SpaceHab does…get the job done, with competent people and good help instead of endless process, unreasonable attitudes, and chaos…it now takes 2.6 times more support personnel and cost to REFLY a payload on ISS-EXPRESS Rack than it cost to develop the original payload and fly it on Shuttle or Spacelab.."

Question/Issue 2: The ISS Payload Data Library requires excessive researcher effort to maintain and is not always used by the NASA payload operations personnel.

The mean score was 3.4, indicating a high level of agreement among the respondents. The significant factor in the responses to this question was the higher number of 0 scores, indicating that the survey respondents had less direct involvement with PDL than with the other questions.

Some comments were as follows:



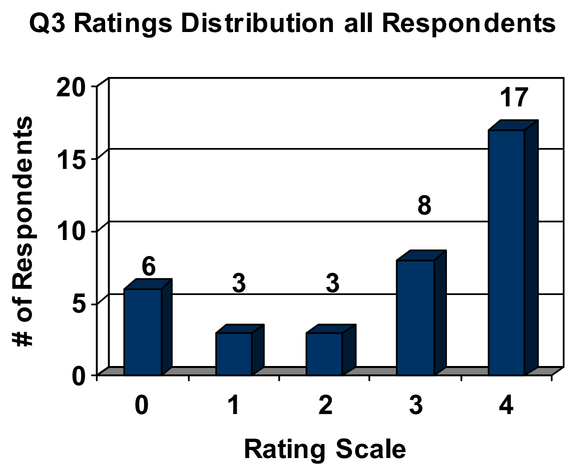
- "By the time one understands how PDL works and where the information is, the hardware is back from the mission."
- "PDL should be modified to be user friendly to the PD…PD should not have to enter the same information two times…concept is good, implementation of PD side fails…"

- “PDL is well organized….excessive effort is caused by the organization of PDL data by flight or increment…since many payloads will operate over several flights organize PDL forms so that launch and return flights are identified and all on-orbit data entered once…”
- “True, most of the time the payload operations personnel say they still require separate paper copies of procedures, CoCs, drawings, etc….be submitted directly to them…”
- “Dealing with the PDL is a nasty experience. This database is poorly suited to life sciences research….”

Question/Issue 3: ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to unnecessary degree.

The mean score was 3.3, with some of the following comments:

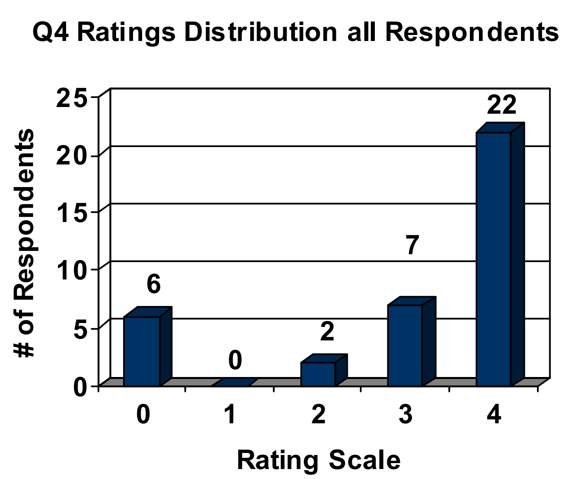
- “The problem is not really adherence. The contents of the standards and programmatic requirements are not focused on the needs of the investigators. The problem pervades the whole program.”
- “…for pre-flight operations this is true…..support from POIC cadre for on-orbit testing has been excellent and accommodating…”
- “…process seems to require "simple to operate" experiments to conform to integration processes that may be appropriate for complex, interactive experiments…perhaps one size does not fit all…”
- “This is especially difficult when IDD and reporting requirements are constantly changing…change the payload operations philosophy that if a payload has been flown before it makes no difference…therefore it must be redesigned, rebuilt, etc….”



Question/Issue 4: ISS Payload operations planning and execution practices are overly formalized with multiple approval levels.

The mean score was 3.6, with some of the following comments:

- “Currently Operations Change Request must be submitted before discussions with flight controller…discussion before submission would ease the process…”
- “ISS should be used as a research lab…PDs should have access to people doing the work…crew should not be inaccessible…”

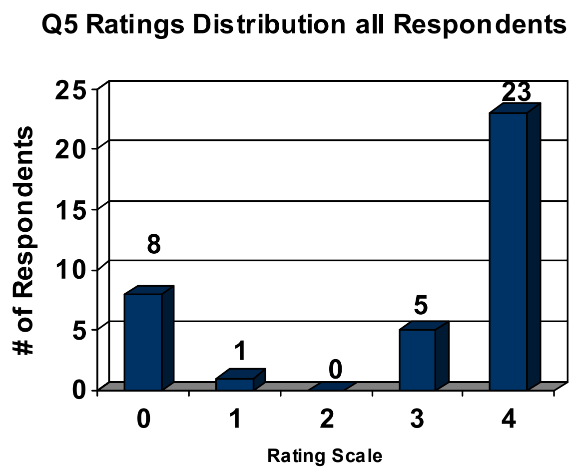


- "….pre-flight planning is overly formalized and rigid, short-term and real-time re-planning that occurs daily is very flexible…"
- "True, the way it is handled now is endless chaos…eliminate endless telecons and practice sessions prior to required program reviews…"
- "Many operations practices are a hindrance to actually getting the work accomplished in a timely fashion…"
- "When the PD submits an OCR via PIMS, the reviewers sometimes review and comment on the entire procedure instead of the documented changes…the PD has to defend a position that has already been approved/decided upon…"

Question/Issue 5: Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily

The mean score was 3.7, with some of the following comments:

- "Payload operations process and reviewing of procedures needs to be standardized…there were five reviews of experiment procedures…changes were due to differing standards."
- "There seem to be too many people involved in the 'paper work' aspect of ISS ops…Direct contact between the science team and crew is too limited."
- "This is definitely true although it has been improving some. There is still inconsistency in interpretation based on the individual doing the evaluation of a product, but the range of inconsistency has been narrowing…"



- "Not only multiple changes in interpretations, but the fact that different members of the payload staff had differing opinions as to what the requirements really meant."
- "Procedures regarding displays are hard to develop due to changes by the PDRP…procedures without displays are simpler to write…"
- "Changes in interpretation of procedure requirements occur often and seem unnecessary…overall procedure seems to complex…goes through too many channels…"
- "Some requirements have no value-added. Procedures go through too many hands and the PDs may not see the final product unless they ask…The process for submitting and revising procedures to the program is way too complex…"

2.4.3 Respondent Characteristics

The number of respondents distributed across RPO and Headquarters organizations is shown in Exhibit 2-1:

Exhibit 2-1. Distribution of POCASS Researcher Questionnaire Respondents by Codes

Position	Summary	RPO					Headquarters Code				
		FB	HLS	MRPO	OSF		M	UB	UF	UG*	UM*
PI	18	3	7	7	1		1	8	2	6	2
PD	11	1	0	5	5		5	0	1	3	2
Both	8	0	1	3	4		4	1	0	2	1
Total	37	4	8	15	10		10	9	3	11	5
*One PI worked with both code UG and UM											

At the time the questionnaire was sent out, Increment 4 was flying on the ISS. The following results represent the ISS-flight/increment-related experience of the 37 respondents:

- 23 had payloads flying during Increment 4
- 7 were flying a payload on ISS for the first time during Increment 4
- 19 had flown more than increment by Increment 4
- 6 will fly their first ISS payload on Increment 5 or 6
- 24 had flown payloads on at least one increment prior to Increment 4
- 22 will have flown multiple increments by Increment 6

Exhibit 2-2 indicates the substantive comment volume by question by researcher group. The greatest number of comments (47) came from payload developers who suggested they have more direct contact with the NASA payloads processes than the PIs might have, particularly some of those who are in the life sciences research discipline and who indicated that they are somewhat more “shielded” from these processes. The five additional PD inputs were received from PD associates who were not directly solicited in the survey.

Exhibit 2-2. Number of Substantive Comments Provided by Questions by Researcher Group

Researcher Group with Total number of respondents indicated in Parentheses	Question 1 1. Current ISS payload practices (not confined to payload operations) are resulting in a document burden on the Principal Investigators that is significantly greater than for Spacelab or other past human space missions.	Question 2 2. The ISS Payload Data Library requires excessive Researcher effort to maintain and is not always used by the NASA Payload Operations personnel	Question 3 3. ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to an unnecessary degree	Question 4 4. ISS Payload operations planning and execution practices are overly formalized with multiple approval levels	Question 5 5. Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily	Total Number of Comments by Group
PI (18)	5	5	5	5	7	27
PD (11 + 5 Additional Inputs)	10	10	9	9	9	47
Both PI//PD (8)	5	4	4	4	5	22
Column Totals	20	19	18	18	21	96

2.4.4 Examples of Researcher Experiences

To further expand on the issues identified from the researcher's perspective, examples were collected for three ISS payloads:

- Protein crystal growth
- Inorganic crystal growth
- Micro-encapsulation of drugs

Researchers on the Study Team have already flown these three payloads on the ISS. The payloads first flew on Shuttle missions and were modified or redesigned for ISS.

The examples provided encompass both payload operations and payload integration; both sets of examples are provided to illustrate the pattern of issues the Team believes is currently endemic to the ISS Program. The examples are summarized below in Exhibits 2-3 and 2-4. More details on the examples are provided in Appendix D.

2.4.5 ISS Payload Integration Process Improvements

The POCAAS Team applauds the accomplishments of the Program Office initiative to improve payload integration processes. The briefing by Jim Scheib to the ISS Independent Implementation Review on October 10, 2001, identified a number of improvements that were accomplished and an ongoing process for continuous improvement. The improvements achieved include the following:

- Comparison of ISS and Shuttle processes to consolidate practices
- Shortened payload engineering integration process

Exhibit 2-3. Payload Operations Examples

Example	Issue
Crew procedures	Reflight MEPS payload from Shuttle. Two-page procedure required 8 months and 77 revisions for ISS.
Crew training certification	PIs with multiple flight experience on Shuttle required to take training course for certification to train crew
PDRP authorization letter required to fly payload	Authorization letter required from PDRP testifying to experiment operability prior to flight
PDRP process	Longer and more expensive than necessary
Multiple inputs of identical information	Data must be re-entered into PDL for each payload, for each increment, and for each flight. Re-entered when hardware is moved
Non-use of PDL	During ZCG-FU turnover at KSC, Stowage had out-of-date drawing. Correct drawing was in PDL. PD required to resubmit separate copy.
Crew procedure change	Procedures conforming to standards get change requests from different crews; e.g., “check-mark” vs. “verify” use
Procedure commonality between ISS and SSP	ISS does not recognize existing SSP accepted procedures but requires new “usability certification”
Procedure delivery date	Requirement to submit final procedures for a reflight experiment at I-7 results in costly change process
Procedure configuration control for onboard experiments	No clear process for configuration control of experiment procedures onboard

Exhibit 2-4. Payload Integration Examples

Example	Issue
Electrical bonding of payload structures	Bonding certification requires two documents. Recertification is required again for experiment remaining onboard thru next increment
Label standard	Requirement to redo faceplate because of square versus rounded corners on lines grouping switches
Payload faceplate color	Shuttle reflight payload requires rework to change face plate color
Resubmittal of PIRNs and COFRs	PDs required to resubmit PIRN and COFR for every flight, even if remaining on-orbit
Microgravity testing of ZCG-FU hardware	$20,000+ spent accomplishing tests rather than accept engineering evaluation
Acoustics verification	Acoustic limits are unrealistic
Safety data packages	Ground and Flight Safety Data Packages contain much the same information, but require separate documentation and review processes
Document change review	PD teams required to review and comment to PIRNs, CRs, facility documentation, unbaselined documents, coordination copies, draft issues, initial release, and white papers
Program requirements on payloads document	Serious cost impact to all existing hardware and will impact costing of new hardware; doubles cost of payload development
Drawing requirements	Engineering drawing required for every item onboard ISS (e.g., standard K-Mart videotape cassette)

- "Fenced Resources" to enhance payload manifest stability
- Allocation of payload crew time as part of "Fenced Resources"
- Steps to consolidate review of procedures, displays, and planning data
- Creation of a streamlined integration process for "Small Pressurized Payloads"

While the Study Team recognizes the accomplishments already achieved, the obvious patterns of response in both the Researcher Issues Survey (Section 2.4.1) and the Examples (Section 2.4.3) are indicative of both dissatisfaction in the research community and unnecessary labor cost within the ISS Program. The patterns also indicate that issues exist in both payload operations and the broader payload integration, and that improvements must be sought by reengineering of payload integration, including but not limited to payload operations.

Recommendation. The current continuous improvement approach should be extended to focus on reduction of requirements and processes that are burdensome to the researchers, and to examine reengineering alternatives as well as continuous improvement. Reduction in requirements and streamlining of processes will reduce both payload operations and payload integration costs.

2.5 Observation: ISS Need for Payload Advocacy

The researchers on the POCAAS Team identified, and the full Team endorsed, the observation that the role of the ISS lead payload operations organization is important as an advocate for science within the Program. The Team believes that the payload operations leadership must have the stature and independence to fulfill that role.

The Team also observed that the MSFC payload operations organization is effective in providing this leadership role. Their knowledge and experience in payload operations integration represents a unique resource to the program.

This observation is not intended to diminish the importance to the program of similar skills that exist in individual scientific discipline areas resident at other NASA Centers and in the Space Shuttle Program Office at JSC.

3. Payload Operations Baseline

To understand current ISS payload operations, the Study Team established with the ISS Program Office a budgetary, mission, and current operations architecture baseline for the Study. Because the Program is currently in a state of flux pending resolution of larger budgetary issues, the baseline established for the Study was essential to the quantification of cost results. While the qualitative findings of the Study Team are largely independent of the baseline, cost is a function of the specific mission requirements imposed upon payload operations. The Program baseline is presented in this Section.

3.1 Payload Operations Budget

The baseline budget is the FY2002 President's Budget Submission (PBS). The budget elements associated with payload operations are contained in the ISS Research Budget, shown in Exhibit 3-1.

Payload Operations budget elements, within the context of this study, are contained in both the Research Programs and Utilization Support categories of the budget. These elements are further broken out in Exhibit 3-2. An expansion of the Payload Integration and Utilization line item is shown in the upper section of Exhibit 3-2. The budgets for the several TSCs are excerpted from within the Research Programs category, and shown in the lower section of Exhibit 3-2.

In Exhibit 3-3, the specific line items defined as Payload Operations in the context of this study are shown. These items are excerpted from Exhibit 3-2 and summed. Each line item is identified and briefly described below, and each function is then further discussed in Section 3.3 of this report. The payload operations budget as shown in Exhibit 3-3 is used as the payload operations reference budget in the further cost analyses provided in the POCAAS.

- The **TSC** budget lines are for each of the TSCs located at the NASA Centers shown. The TSCs and their functions are described later in this section.
- The **NISN (SOMO)** line item is the budget for the payload operations communications services obtained from the NASA Integrated Services Network (NISN), which provides communications services across all of NASA.
- The **Enhanced Communications for Payloads** line provides for an enhancement of the ground systems that process the ISS KuBand data downlink, increasing the capability to distribute data from 50Mbs (current) to 150Mbs (the current capability of the air-to-ground transmission segment).
- The **P/L Training – TSC (PTC)** line item funds completion of the development of the Payload Training Complex (PTC), which is located at JSC and is used to train ISS flight crews to operate payloads. The Training Systems Contract is the development contract for the Space Station Training Facility (SSTF), including the PTC, and is phased out as development is completed.

Exhibit 3-1. ISS Research Budget (FY2002 PBS)

	SAT	UPN	FY02		FY03		FY04		FY05		FY06		Total FY02-06	
			Rephase		Rephase		Rephase		Rephase		Rephase		Rephase	
FY01 President's Budget				451.6		535.7		540.8		552.3		534.6		2615.0
Research budget reduction				-168.0		-188.5		-202.1		-205.2		-216.8		-980.5
Research program			8.112	283.6	0.523	347.2	0.303	338.7	1.030	347.1	0.530	317.8	10.498	1634.5
Reserves			8.112	19.261	0.523	44.934	0.303	25.067	1.030	40.222	0.530	36.871	10.498	166.355
Content			8.112	264.345	0.523	302.221	0.303	313.673	1.030	306.927	0.530	280.976	10.498	1468.141
RESEARCH PROGRAMS			**5.360**	**132.664**		**179.267**		**179.939**		**186.124**		**159.791**	**5.360**	**837.784**
Gravitational Biology & Ecology	200	393		30.000		35.100		34.600		24.101		26.301		150.102
Biomedical Research & Countermeasures	300	394		21.882		27.914		25.606		26.516		25.526		128.444
Microgravity Research	400	398	3.560	61.652		97.046		98.594		114.957		87.889	3.560	460.138
Space Product Development	500	493	1.800	15.735		15.761		17.960		17.960		17.960	1.800	85.375
Earth Observation Systems	600	495		3.395		3.446		3.179		2.590		1.115		13.725
UTILIZATION SUPPORT			**2.752**	**131.681**	**0.523**	**122.954**	**0.303**	**133.734**	**1.030**	**120.803**	**0.530**	**121.185**	**5.138**	**630.357**
Flight Multi-user Hardware & Support	700	496	2.340	49.331	0.520	46.404	0.300	40.398	1.030	35.556	0.530	35.529	4.720	207.218
Payload Integration & Operations	700	479	0.412	82.350	0.003	76.550	0.003	93.336		85.247		85.656	0.418	423.139

Exhibit 3-2. Expansion of Payload Integration and Operations Budget Line

	SAT	UPN			FY02		FY03		FY04		FY05		FY06		FY02-06	
479 PAYLOAD INTEGRATION AND OPERATONS					**0.412**	**82.350**	**0.003**	**76.550**	**0.003**	**93.336**		**85.247**		**85.656**	**0.418**	**423.139**
NA	700	479-20	JSC	PAYLOAD SAFETY REVIEW PANEL		0.945		0.945		0.945		0.945		0.945		4.725
OA	700	479-21	JSC	PRIME		22.354		17.245		15.685		13.405		13.295		81.984
TA	700	479-24	JSC	NISN (SOMO)		4.100		4.500		5.000		5.500		5.700		24.800
TA	700	479-41	JSC	ENHANCED COMMUNICATIONS FOR PAYLOADS						16.044		5.252		3.561		24.857
DA	700	479-42	JSC	P/L TRAINING CAPABILITY – TSC (PTC)	0.400	1.000		0.400		0.420		0.257			0.400	2.077
MA	700	479-42	JSC	P/L TRAINING CAPABILITY – SFOC (PTC)		1.050		1.875		1.875		2.058		2.335		9.193
DA	700	479-43	JSC	PAYLOAD PLANNING SYSTEM (PPS)		0.300										0.300
OA	700	479-80	JSC	ISSPO SUPPORT (SAIC) Ned		1.105		1.105		1.205		1.205		1.205		5.825
EA	700	479-82	JSC	COMM OUTAGE RECORDER (COR)		0.066										0.066
	700	479-70	KSC	UTILIZATION GROUND PROCESSING		5.972		5.530		5.279		7.935		7.906		32.622
	700	479-71	KSC	HANGER L SUPPORT		2.358		2.550		2.708		2.815		2.929		13.360
	700	479-22	MSFC	P/L OPS & INTEG FUNCTION (POIF)	0.012	22.000	0.003	23.900	0.003	25.100		26.000		26.850	0.018	123.850
	700	479-23	MSFC	ENGG INTEG / P/L DATA LIBRARY (PDL)		1.600		0.600		0.550		0.550		0.750		4.050
	700	479-XX	MSFC	POIC & PDSS: P/L OPS & INTEG CENTER (POIC)		18.400		17.100		17.775		18.225		19.080		90.580
	700	479-43	MSFC	PAYLOAD PLANNING SYSTEM (PPS)		1.100		0.800		0.750		1.100		1.100		4.850

EXCERPTS FROM RPO BUDGETS																
				ARC TELESCIENCE CENTER		1.665		1.128		1.139						3.932
				JSC TELESCIENCE CENTER		0.218		0.218								0.436
				GRC TELESCIENCE CENTER		1.000		1.000		1.000		2.400		1.600		7.000
				JPL TELESCIENCE CENTER						0.144		0.750		0.766		1.660
				MSFC TELESCIENCE CENTER		0.360		0.369		0.350		0.325		0.325		1.729
						3.243		**2.715**		**2.633**		**3.475**		**2.691**		**14.757**

Note: JSC TSC presentation identifies full cost as $2,391,929/year (19.5 FTE)

Exhibit 3-3. Payload Operations Reference Budget

SAT	UPN		ITEM	FY02	FY03	FY04	FY05	FY06	FY02-06
FROM 39X RESEARCH PROGRAMS									
200	393-251	ARC	ARC TELESCIENCE SUPPORT CENTER	1.665	1.128	1.139			3.932
700	394-991	JSC	JSC TELESCIENCE SUPPORT CENTER (see Note)	0.218	0.218				0.436
400	398-251	GRC	GRC TELESCIENCE SUPPORT CENTER	1.000	1.000	1.000	2.400	1.600	7.000
700	398-551	JPL	JPL TELESCIENCE SUPPORT CENTER			0.144	0.750	0.766	1.660
700	398-961	MSFC	MSFC TELESCIENCE SUPPORT CENTER	0.360	0.369	0.350	0.325	0.325	1.729
FROM 479 PAYLOAD OPERATIONS AND INTEGRATION									
700	479-20	JSC	NISN (SOMO)	4.100	4.500	5.000	5.500	5.700	24.800
700	479-41	JSC	ENHANCED COMMUNICATIONS FOR PAYLOADS			16.044	5.252	3.561	24.857
700	479-42	JSC	P/L TRAINING – TSC (PTC)	1.000	0.400	0.420	0.257		2.077
700	479-42	JSC	P/L TRAINING – SFOC (PTC)	1.050	1.875	1.875	2.058	2.335	9.193
700	478-43	JSC	PAYLOAD PLANNING SYSTEM (PPS)	0.300					0.300
700	479-22	MSFC	PAYLOAD OPS & INTEG FUNCTION (POIF)	22.000	23.900	25.100	26.000	26.850	123.850
700	479-XX	MSFC	POIC & PDSS: P/L OPS & INTEG CENTER (POIC)	18.400	17.100	17.775	18.225	19.080	90.580
700	479-43	MSFC	PAYLOAD PLANNING SYSTEM (PPS)	1.100	0.800	0.750	1.100	1.100	4.850
				51.193	**51.290**	**69.597**	**61.867**	**61.317**	**295.264**

- The **P/L Training – SFOC (PTC)** line item funds training instructors provided by the Space Flight Operations Contract (SFOC) to train ISS flight crews in payload operations. As PTC development is completed, PTC maintenance is also phased over from the TSC contract to the SFOC contract.
- The **JSC Payload Planning System (PPS)** line item funds development of the interface between the PPS, which operates in the POIC, and the Crew Planning System (CPS), located in the Space Station Control Center (SSCC). The interface development is complete after FY 2002.
- The **MSFC Payload Operations and Integration Function (POIF)** budget item funds the staff at MSFC who integrate all ISS payload operations.
- The **MSFC POIC & PDSS** budget funds development and operation of the Payload Operations Integration Center (POIC), which provides information technology support to the POIF, TSCs, and remote principal investigators (RPIs). The POIC also contains the Payload Data Services System (PDSS), which distributes payload data to the IPs as well as to U.S. researchers.
- The **MSFC Payload Planning System (PPS)** line item funds maintenance of the software for the PPS, which is used to schedule all payload activities onboard the ISS.

In the Spring of 2001, the NASA Advisory Council (NAC) chartered the ISS Management and Cost Evaluation (IMCE) Task Force to conduct an independent review and assessment of the ISS cost, budget, and management. In addition, the Task Force was asked to provide recommendations that could provide maximum benefit to the U.S. taxpayers and the IPs within the President's 2001 budget request to Congress.

The POCAAS Study Team took note that the IMCE report made several findings relevant to the POCAAS:

- "The U.S. Core Complete configuration (3-person crew) as an end-state will not achieve the unique research potential of the ISS."
- "Scientific research priorities must be established and an executable program, consistent with those priorities, must be developed and implemented."
- "Additional crew time must be allocated to support the highest priority research."

The IMCE Cost Analysis Support Team Report contained the following findings:

- "<u>5.3.2 Payload Operations Facility</u>. This is now, essentially, a fixed cost due to staffing reductions. Current staff is considered minimal. The staffing profile establishes the potential for higher than anticipated attrition. If such attrition is realized, it is anticipated that the cost of replacing and training staff would exceed current budget estimates and could impact operation capability.
- "<u>5.3.3 Remote/Automated Payload Operation</u>. Remote or automated payload operation has been suggested as a means of alleviating reliance on a smaller ISS crew. This would, however, necessitate redesign of payloads and incorporation of technology to support such operations. This would result in added cost. The cost would be dependent on stage

of development. Higher cost would be associated with payloads in advanced stages of development. There is also the potential to shift additional cost to sponsors or the Payload Operations Facility."

The POCAAS Study Team agrees with the IMCE principal findings noted above and has given attention in its findings to the need for effective use of crew time available to payloads, as well as the need for an interim means to obtain additional crew time for research tasks.

The POCAAS Study Team does not agree completely with the findings of the IMCE Cost Analysis Support Team. Previous budget reductions have reduced POIF staff to a minimal level for the current mode of ISS Program operations. However, the Study Team believes that further reductions can be made if ISS Program operational requirements, standards of operation, and processes are relaxed to a more cost-effective level, as noted in the many researcher comments contained in Section 2.

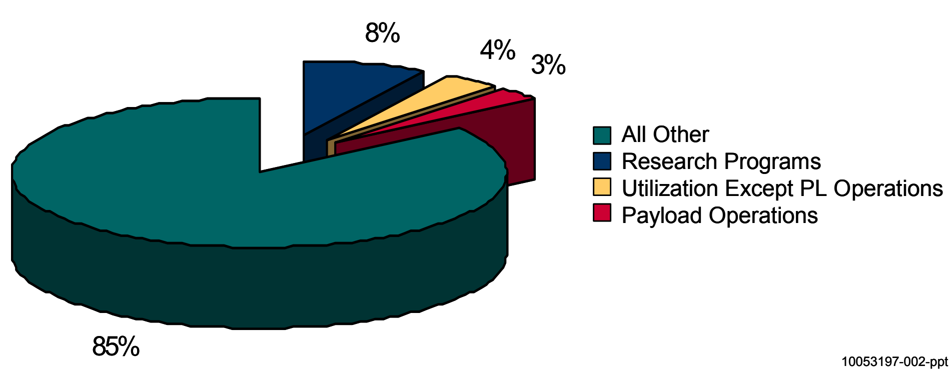
The Study Team also recognizes the performance and cost tradeoffs involved in remote or automated payload operations (telescience), versus manned operations. However, the Study Team observes that many ISS payloads are already designed for telescience and that telescience offers the ability to achieve increased scientific return during and after the period of ISS restriction to a three-person crew.

3.1.2 Budget-Related Findings

3.1.2.1 Payload Operations in Relation to the ISS Budget

The Study Team observes that the Payload Operations budget is only 3 percent of the Program Budget (Exhibit 3-4). However, the Team did not consider 3 percent of the total budget and 20 percent of the Research Program budget as a disproportionate fraction for payload operations in comparison to other programs. While payload operations cost can be reduced, as discussed in this report, other program element costs should be similarly reducible.

Exhibit 3-4. ISS Budget Components



3.1.2.2 Long-Term Payload Operations Planning

The Payload Operations budgets, as presented, appear to represent an extrapolation of today's costs, with consideration of workload variation, as opposed to a plan for evolution of the ISS to a laboratory facility for conduct of world-class science. None of the information presented to the Study Team indicated a long-term plan.

All operational programs undergo a learning curve after operations begin. Although the Team recognizes that payload operations (and other parts of the program) have undergone significant budget reductions within the last year (the first year of on-orbit payload operations), no indication of a continued learning curve in the budget projections exists. Also, while the budget reductions that have taken place can be considered to have been absorbed within the operational learning curve, no evidence exists of corresponding changes in operations requirements and methodology, based on the experience gained.

In a multi-year research program, changes in operations requirements and the resulting implementation must be anticipated, and should be planned for. These changes are, of course, dependent upon the multi-year research program itself. The Team found no evidence of an integrated plan for evolution of the research program and no plan for the evolution of payload operations through the multi-year program. Indeed, the Team experienced difficulty in obtaining research projections beyond the immediate (1 year) flight increments.

The Team also observes that the rapid progress now occurring across the broad area of information technology is a powerful dynamic affecting the way research in general is performed, as well as a powerful tool for increased productivity. However, the application of information technology advances in the payload operations infrastructure requires planning and budget investment, which can be recouped in reduced operating costs. The Team did not find long-term planning anticipating the changes in the way science will be done and in the application of information technology advances to facilitate science.

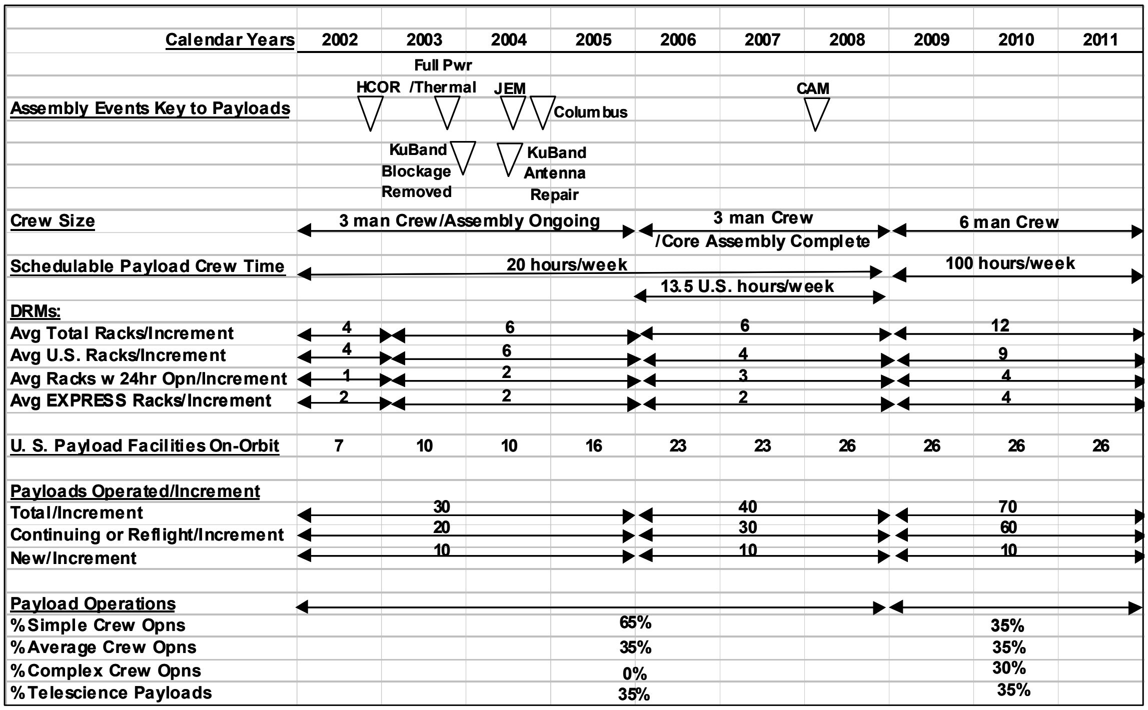
Recommendation. A multi-year plan for operations evolution should be established and maintained. The plan should be reflective of the evolution of research needs and should guide the introduction of technology and development of critical operations skills.

3.2 Program Requirements on Payload Operations

3.2.1 Mission Model

In consultation with the ISS Program Office, the POCAAS Team developed a Mission Model to help characterize the payload operations workload. The workload is depicted in Exhibit 3-5.

Exhibit 3-5. Mission Model for Payload Operations



Note: Model based on three-month increments

3.2.1.1 Assembly Events

At the time of this report, ISS budget constraints were under evaluation, and the continued on-orbit assembly schedule was under review. For purposes of the study, the assembly events considered key to payload activities are assumed as shown in Exhibit 3-5. The current KuBand antenna blockage will be removed when the ISS reconfiguration to provide full power and cooling capability takes place. The repair of the antenna to remove the current constraints associated with the failed gimbal heaters has not been manifested but is expected to occur in the time frame shown.

The Mission Model assumes that the ISS will achieve its full planned power and thermal control capability, and correction of current KuBand communications limitations, within the 2003 time frame. These accomplishments will significantly reduce POIF workload currently experienced due to these constraints.

The assembly of the JEM and Columbus modules in the 2004–2005 time frame will significantly increase the pressurized volume and facilities available to house payloads. With the accomplishment of these milestones, the IPs will begin their on-orbit payload activities, which will introduce new interfaces into payload operations. This milestone is defined as Core Assembly Complete for purposes of the POCAAS.

The delivery of the Centrifuge Accommodation Module (CAM) in 2008 will enable new research capabilities in biology, including more complex experiments. However, its use will be limited until increased crew time is available.

3.2.1.2 Flight Crew Size

The availability of flight crew time to support payload operations is a critical resource. The currently funded ISS Program contains accommodations for three crew persons on-orbit. The full ISS design, consistent with the International Governmental Agreement with the IPs, requires a six- to seven-person crew.

For POCAAS purposes, the crew size was assumed to transition from three persons to six persons in the 2009 time frame. During the three-person period, a division was made between pre-Core Assembly Complete, during which crew time is heavily engaged in assembly operations, and post-Core Assembly Complete.

3.2.1.3 Flight Crew Time

The amount of schedulable crew time available for payload operations has been established as an average of 20 hours/week prior to Core Assembly Complete. *Schedulable* is that time allocated within the crew's standard weekday work hours. The crew may elect to additionally use some of their discretionary time for payload activities, but these are not schedulable or predictable. The average number also varies from day to day and week to week, depending upon ISS assembly and maintenance operations schedules.

After Core Assembly Complete, the amount of schedulable crew time has also been assumed to remain to be 20 hours per week. After this milestone, although assembly activities are greatly reduced, maintenance activities are predicted to still consume the majority of crew time. Some projections are pessimistic that 20 hours per week of payload crew time can be maintained.

When a six-person Crew is achieved, a significant increase is expected in the time available for payload operations. The POCAAS has assumed this to be approximately 100 hours per week (6.5 hours per workday times 5 workdays per week times three crew persons = 97.5 hours per week).

3.2.1.4 Design Reference Missions

The ISS Program Office provided several Design Reference Mission (DRM) models to the Study Team. These models were obtained from a Monte Carlo analysis model of ISS payloads maintained by the Program Office. The DRMs evaluate the resource requirements of anticipated payloads versus the resources available onboard the ISS at a specific point in time and indicate the level of payload activity that can be manifested and accomplished for a given mission increment.

Nominal 3-month increments were assumed for the POCAAS, although current increments have been extended to 4 or 5 months. The IMCE Study recommended extension of increments to 6 months. The POCAAS assumed 3-month increments in its analyses but gave consideration to the effects of longer increments.

The DRM analysis shows that power, cooling, and crew time are currently limiting constraints on research manifesting. After final power and cooling capabilities are achieved (late 2003), Shuttle mid-deck transportation and crew time are critical constraints until a six-person crew is achieved.

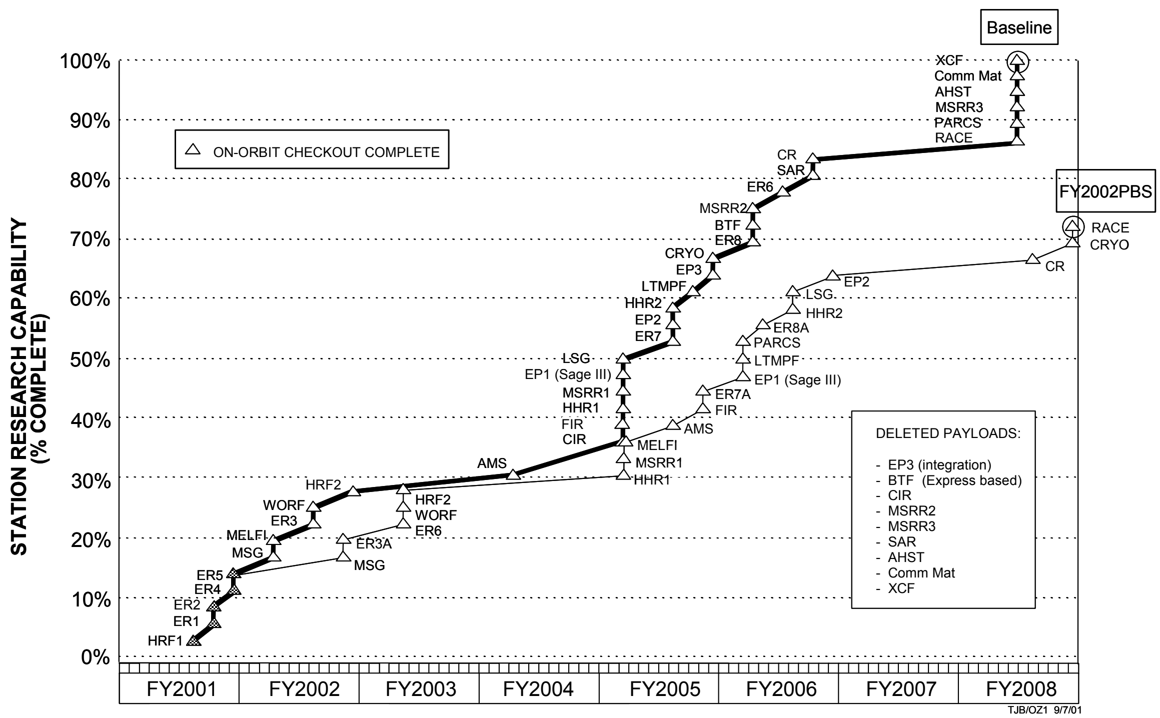
After a six-person crew is achieved, four approximately equal critical constraints will exist: up-mass, keep-alive power, mid-deck transportation, and on-orbit stowage.

3.2.1.5 Payload Facilities On Orbit

Payload Operations workload is driven by the combined U.S. plus IP payload activities onboard the ISS, but more strongly by U.S. payload activities. The U.S. is responsible for integrating all payload activities, but for conducting U. S. payloads only. U.S. payloads can be located in the Columbus and JEM but are still installed in U.S. racks and operated through the U.S. C&DH system.

U.S. Payload Facilities (EXPRESS and dedicated facility racks, other payload equipment) are transported to the ISS as indicated and increase the capability for research activities as they arrive. As the quantity of hardware on orbit increases, the responsibility of the payload operations staff for monitoring and managing the facilities also increases. The facility build-up assumed by the POCAAS is further expanded in Exhibit 3-6. However, the number of payload racks that are actually operated on an increment is limited by other resources, as reflected in the DRMs.

Exhibit 3-6. ISS U.S. Research Facility Delivery Plan



3.2.1.6 Payloads Operated Per Increment

The number of payloads operated per increment also drive payload operations. Timeline scheduling is performed by payload, and crew procedures, displays, and training are all dependent upon the specific payloads to be operated each increment. The total number operated per increment is determined by the resources required and available for the payloads. However, some payloads continue operations from one increment to the next, and some payloads are returned to the ground but then reflown on a later increment. Continuing or reflight payloads require less operations preparation work than new payloads (i.e., never flown before), although the amount of rework required for a reflight will vary with the degree to which the payload itself or the experimental protocol may be altered between flights.

3.2.1.7 Payload Complexity

The operations preparation work required for a payload also varies with the operational characteristics of the payload. Crew support complexity and telescience use were key factors considered by the POCAAS in its analyses.

The Study Team classified payloads currently and previously flown on the ISS in accordance with the crew support complexity definitions shown below. The payload complexity model previously shown in the Exhibit 3-5 Mission Model is based on this analysis. For purposes of analysis, three discrete definitions were used, although in reality crew support complexity varies in a continuum.

- **Simple payload.** Operated with simple procedures requiring little or no specialized crew training (example, Space Accelerometer Measuring System)
- **Average payload**. Procedures require crew activation of payload, periodic servicing, some experiment operations; requires limited training for specialized skills (example, HRF-PUFF)
- **Complex payload**. Requires crew activation of payload, periodic servicing, crew operation of experiment, and significant crew judgments to achieve scientific objectives; research understanding and training for specialized skills is important (example, Fluid Physics Module, Spacelab-1)

The emphasis in these definitions is on the intrinsic characteristics of the payload that drives the crew support requirements. The Study Team's distinction between *average* and *complex* payloads was carefully drawn to distinguish payloads that the Team believes represent the research vision for the ISS, but that are not possible within the 20 hours per week crew time constraint with a three-person crew.

The Study Team considered other definitions (e.g., those currently in use by the training function of POIF) but judged them less appropriate to the POCAAS. The current POIF definitions are less stringent than the POCAAS definitions above and reflect a current ratio of 30 percent Simple, 45 percent Average, and 25 percent Complex payloads.

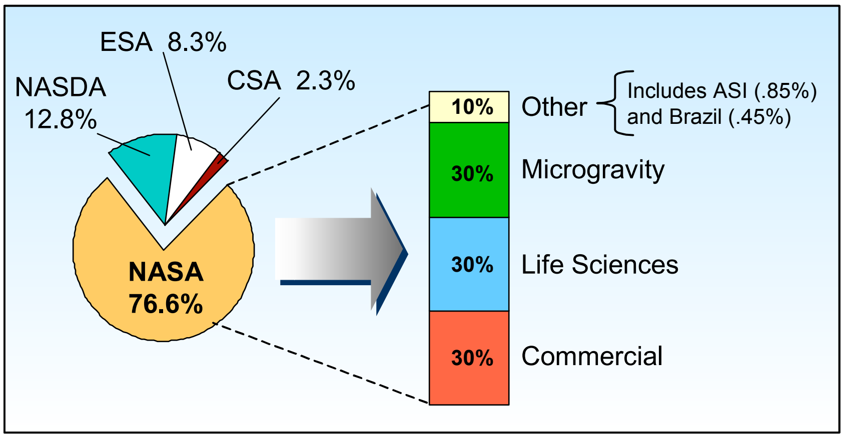
Telescience payloads are principally operated by PI teams through commands from the ground. All current telescience payloads still require the crew to move the payload itself or samples from and to the Orbiter and to install the payload in the ISS. Some require sample exchange or other servicing by the crew. Future payloads mounted externally on pallets will require installation but may require less crew servicing after installation.

Telescience payloads tend to be simple to average from the viewpoint of crew support but generate real-time activity in terms of command traffic and data return. They may operate continuously for extended periods and are typically operated from RPI sites that communicate through the Payload Operations Integration Center. The POCAAS classified current payloads as telescience only if their principal mode of research conduct was through telescience. Payloads that only use ground commands for housekeeping functions were not classified as telescience. Although not reflected in the Mission Model, the Study Team did consider that the use of telescience should be expected to increase over time, as researchers seek to overcome limitations on crew time.

3.2.2 Research Resource Allocation

The ISS resources allocated to research within the U.S./ESA/NASDA elements of the ISS are to be shared as illustrated in Exhibit 3-7. The sharing among the U.S. and the IPs is controlled by the MOUs established among the IP governments. The U.S. sharing of research resources among research disciplines is as directed by the Space Station User Board at NASA Headquarters.

Exhibit 3-7. Pressurized Resource Allocation



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Sharing is to be achieved over a reasonable but unspecified time, but not on a daily or increment basis.

The Russians retain 100 % of the resources within the Russian elements.

3.2.3 Other Key ISS Configuration Constraints

Significant communications constraints exist on payload operations.

Payload commands are restricted to 8 commands per second, but the current effective limit is 1 to 3 commands per second. During periods when the SSCC is uplinking data to the ISS, congestion occurs, and the POIC has been requested at times to reduce command traffic. Commanding is performed through the S-Band communications channel.

The command rate restriction is based on sharing the current single S-band channel. The highest uplink traffic is file uplinking for crew procedures, software updates, and similar data traffic. This uplink traffic is executed and managed by the SSCC; the POIC places data files for uplink in an outbox, from which the files are retrieved and transmitted by the SSCC.

As telescience increases, and as crew size is increased, uplink requirements will increase.

The KuBand communications channel is used heavily to downlink payload data, as well as to downlink ISS television. During periods when there is no communication coverage through the TDRSS, both systems and payload data are recorded onboard and later downlinked via KuBand.

With the current configuration of the ISS, KuBand coverage is limited while in x-axis parallel to orbital plane (XPOP) attitude to about 34 percent, with an average AOS of 27 minutes. After flight 12A, ISS attitude will be restricted to local vertical-local horizontal attitude, and KuBand coverage will be reduced to about 29 percent, with an average AOS of 10 minutes.

After the photovoltaic array that blocks the KuBand antenna is relocated to its final planned location, and after the failed gimbal heaters on the KuBand antenna are repaired, KuBand coverage will increase to a maximum of about 55 percent.

Because of the communications limitations, and the significant use of telescience for payload operations, the addition of Timeliner capability is important. Timeliner is an onboard software system to allow the storage of timed command sequences, which are executed independently of ground coverage. This capability is planned for June 2002.

3.2.4 Program Requirements Findings

Limitation on conduct of research. The limitation of a three-person crew represents a principal constraint to payload operations. The limitation is not only in crew time for payload operations, but importantly with regard to crew selection. In a three-person crew, the majority of time on the ISS is spent in maintenance and housekeeping activities for the ISS itself, including extra-vehicular activities, with a current 20 hours per week available for schedulable payload operations. This level of crew time means that most of the payload time is spent in experiment installation, troubleshooting, servicing, and sample return activities, with little time for real scientific investigation by the crew. With this workload, the required crew skill set emphasizes generalists, rather than specialists, and technicians, rather than scientists. This greatly limits the opportunity to fly career scientists, who are willing to take a period of time from their scientific pursuits to train and fly in exchange for the opportunity to perform science in space, but who are unwilling to cease being scientists.

Restriction on science disciplines. The limitation of a three-person crew also affects the science disciplines, in that some disciplines are more adaptable to telescience and minimum crew time than others. Human life sciences and fundamental biology operations tend to be crew-intensive and will be most affected by crew time limitations.

Need for three-person crew operations concept. Because this will be the mode for a period of years, the development of the most effective three-person crew operations concept is essential. The use of telescience and autonomously operated experiments is essential to accomplishing maximum science with constrained crew resources. Therefore, the vision of easy, effective telescience must be pursued. "Layers" of infrastructure that separate ground-based PIs from accessing and operating their experimental apparatus must be minimized.

Because the unique value of the ISS is its onboard crew operations and frequent logistics access, experiments should also be designed to minimize the crew time spent in installing, activating, maintaining, and servicing equipment, so as to maximize use of the available crew payload time for real scientific activities.

Need for increased communications. With increased emphasis on telescience comes increased need for air-to-ground communications. Increased KuBand communications coverage should be pursued through such options as adding a second KuBand antenna and operational use of the NASDA KaBand system. (The KaBand system is compatible with the U.S. TDRSS, although it is planned for operation with NASDA's own communications relay satellite system.) Increased uplink capacity will be particularly needed, both for data file uplink and payload commanding.

Multiple experiment classes. Another unique aspect of the ISS is the broad range of scientific disciplines it is expected to support (life sciences, microgravity sciences, commercial payloads, other space sciences) and the variety of experiment designs (simple to complex, crew and telescience, discipline facilities, and individual payloads). This diversity dictates that a flexible portfolio of alternate operations service levels and processes must be developed. A one-size-fits-all approach will necessarily result in overkill and unnecessary cost for the majority of simpler payloads.

3.3 Current Payload Operations Architecture

This section discusses the current ISS payload operations architecture. The POCAAS defines *architecture* to begin with the operational functions to be performed, the allocation of functions to operations elements (i.e., facility and/or organization), and the relationship among the elements.

3.3.1 Payload Operations Functions

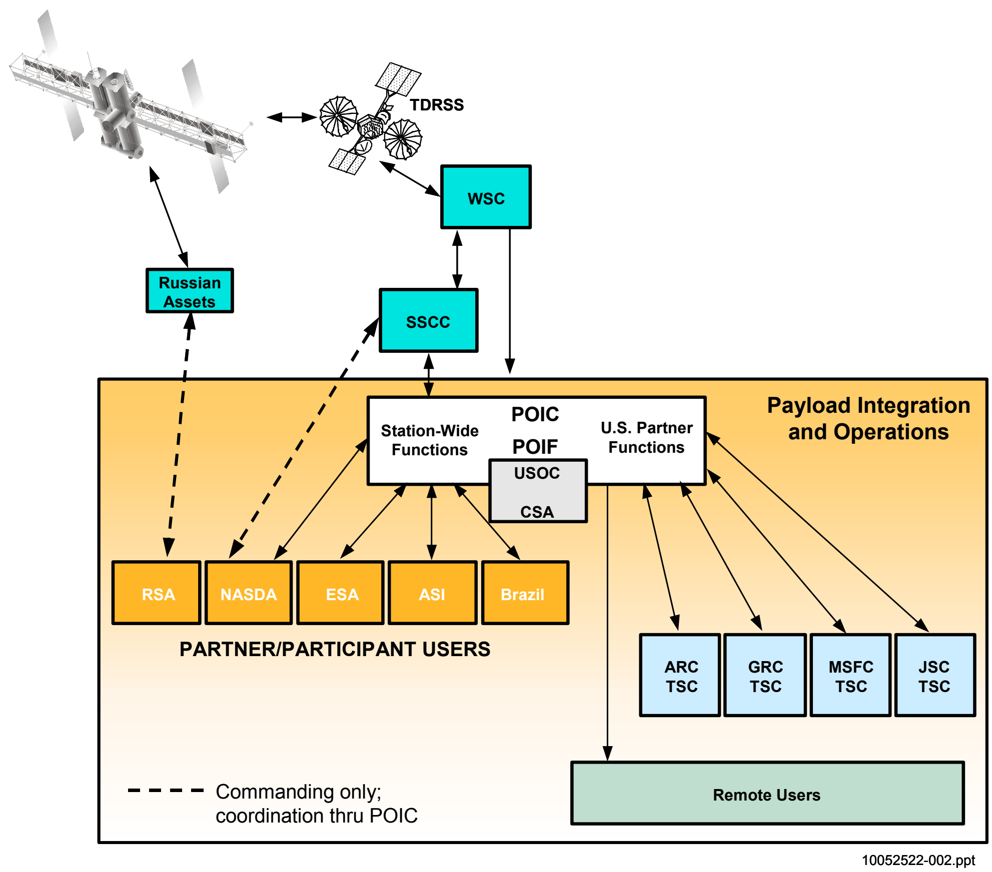
The functions identified by the POCAAS, and considered necessary for ISS payload operations, are listed below. These functions are derived from the payload operations principles and concepts described in Section 2 of this report.

- Coordinate and integrate all U.S. and IP payload operations
- Plan and integrate the timeline for operation of payloads
- Provide single interface to the SSCC for payload operations
- Perform real-time control of payloads and supporting systems
- Develop procedures and perform control of payloads
- Develop procedures and perform control of PLSS
- Integrate experiment procedures and flight displays
- Integrate and prepare the PODF
- Train flight crew and ground support personnel
- Ensure payload safety critical operations are conducted in consonance with established safety protocols
- Provide information technology infrastructure
- Distribute, process, and display telemetry and other electronic data for U.S. payloads
- Distribute KuBand payload data to IPs
- Process and transmit commands
- Implement payload telemetry and command database to enable processing
- Enable communications among all payload operations elements
- Provide tools to support information retrieval, planning, and coordination

3.3.1 ISS Operations Elements

ISS operations for both core systems and payloads are geographically distributed. This distribution is necessitated by the international participation in construction and operation of the ISS and by the diversity and long-duration aspect of ISS payloads. It is impractical to locate all operations functions in one location. The current ISS operations elements are shown in Exhibit 3-8.

Exhibit 3-8. ISS Operations Elements



WSC. The White Sands Complex is the communications hub for air-to-ground (A/G) communications with the ISS, through the TDRSS.

SSCC/SSTF. The SSCC, located at JSC, has operational responsibility and control for the ISS as a whole. The Space Station Training Facility (SSTF), also located at JSC, is the central facility where all ISS crew training is performed. The PTC is an element of the SSTF.

POIC/POIF. The POIC, located at MSFC, houses the central information technology infrastructure for payload operations and hosts the POIF. The POIF consists of the staff who plan and perform the integration of ISS payload operations, and who operate the PLSS.

USOC. The U.S. Operations Center (USOC) is a portion of the POIC that provides facilities for PIs who may wish to operate their ISS payloads from that location. The Canadian Space Agency (CSA) operates through the POIC and SSCC.

PCCs. The Partner Control Centers (PCCs) are operational facilities operated by each of the IPs (Russia, NASDA, and ESA) and located in each IP country. A PCC operates both the core systems and payloads in its respective on-orbit element, except U.S. experiments located in IP elements are operated through the POIC using the U.S. C&DH system. The ASI and Brazil PCCs operate only payloads (no core systems).

RPIs. As a basic principle of research, ISS payloads are operated by their PIs, usually from their home location due to the extended duration of operations. These investigators are remote from the POIC; therefore and are termed RPIs locations.

TSCs. Telescience Support Centers are established at the ARC, GRC, MSFC, and JSC. The TSCs are principally established to operate facility-class payloads onboard the ISS. A facility-class payload is typically a rack of equipment that enables investigations into a particular scientific discipline or subdiscipline by providing common systems and services required by multiple experiments in that discipline. In this sense, the TSCs can be viewed as a "super-RPI" site, because multiple PIs may use the facility-class rack resources through the TSC. The TSCs also provide other scientific discipline-related services.

NISN. The NASA Integrated Services Network provides the communications services necessary to link the other operational elements together.

3.3.3 Distribution of Payload Operations Functions Across Elements

The distribution of payload operations functions across elements is summarized in Exhibit 3-9.

3.3.4 POCAAS Findings Regarding Current Payload Operations Architecture

The Study Team did not identify any significant overlap in functions among operations elements. The Team noted that all of the U.S. elements are heavily dependent upon the POIC to provide basic information services.

The U.S. elements do not interact with the IP C&DH systems (nor do the IP C&DH systems interact among themselves.) Although the IP elements are dependent upon the POIC for distribution to them of KuBand data, the PCCs do not interact directly with the U.S. C&DH system. Thus, a compartmentalization of IT infrastructure is implicit in the ISS design.

These observations do not mean that some specific system functions might not be more cost-effectively redistributed among elements. (For example, the distribution of KuBand data from WSC rather than the POIC is a possibility). Architectural alternatives are evaluated in Section 5.

Exhibit 3-9. Functions Across Elements

Function	SSCC/SSTF	POIF/POIC	PCCs	TSCs	PIs/PDs
• Coordinate /Integrate	Integrate ISS	• Integrate all PL Operations • Single Interface to SSCC	• IP Core systems • IP PLSS • IP PLs	Research Facilities	N/A
• Timeline Planning	Integrate ISS	• Integrate all PLs	• IP PLs	Research Facilities	Experiments
• Real Time Control	ISS Core Systems	• U.S. PLSS • Support U.S. PIs	• IP Core Systems • IP PLs	Support PIs	Experiments
• Develop Displays/ Procedures	ISS Core Systems	• U.S.PLSS • Integrate all PLs	• IP PLSS • IP Expts	Research Facilities	Experiments
• Train Flight /Gnd Crews	• ISS Core Systems • Host PLs	• Integrate all PLs/Deliver U.S. PL Training	• IP PLSS • IP PLs	Research Facilities	Experiments
• U.S IT Infrastructure	ISS Core Systems	U.S. Payloads	IP Payloads	Research Facilities	Experiments
• Telemetry Processing	ISS Core Systems	• U.S. PL Data • U.S. C&DH	• IP Data • IP C&DH	• POIC (Trek) • Expts	• Expt Data Streams • POIC(Trek)
• Command Processing	Integrated ISS	• All PL Cmds • U.S. C&DH	• IP Cmds • IP C&DH	• POIC (Trek) • Expts	• Expts • POIC (Trek)
• TM/CMD Database	Integrated ISS	• All PL Data • U.S. C&DH	• IP Data • IP C&DH	• Research Facilities	• Experiments
• Communications (All WAN provided by NISN)	ISS Television Processing	Voice, Video and Data Distribution to PL Elements	IP Distribution	Internal Voice, Video, & Data Distribution	Within Experimenter Facilities
• Tools	CPS	• CPS/PPS • PIMS • OCMS	IP Tools	Research Facility Tools	Experiment Tools
• KuBand to IPs	N/A	PDSS	N/A	N/A	N/A

Section 4. Current Architecture and Cost Reduction Options

This Section discusses the elements of the current ISS payload operations architecture and possible cost reduction options. The following elements are discussed:

- Payload Operations Integration Function
- Payload Operations Integration Center
- Telescience Support Centers
- NASA Integrated Services Network

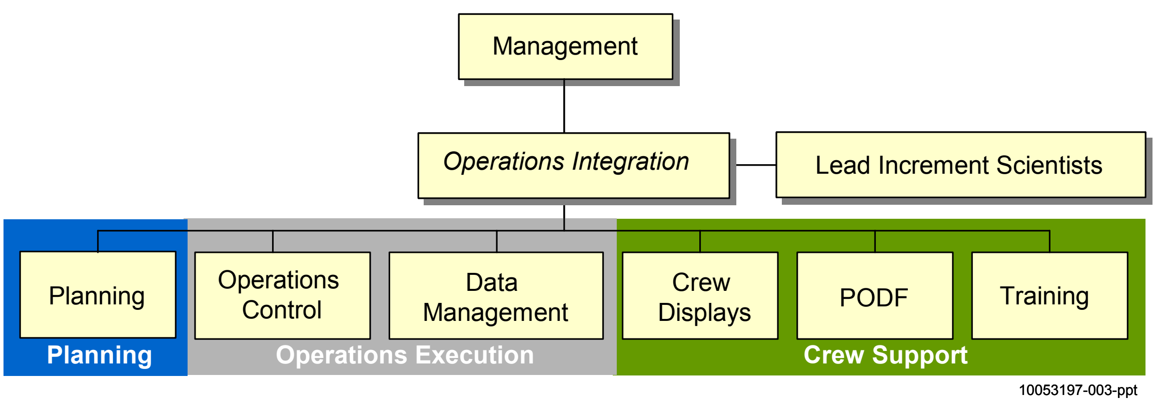
Each element will be discussed in sequence, together with cost-reduction options applicable to that element. Finally, all cost-reduction options will be discussed as a whole.

4.1 Payload Operations Integration Function (POIF)

4.1.1 Current POIF Description

The POIF comprises the staff who plan and perform the integration of ISS payload operations and who operate the PLSS. The POIF is organized around nine major functions, shown in Exhibit 4-1. The descriptions of these functions provided below are intended to be illustrative and are not exhaustive. Many of the functions require coordination of activities with other ISS Program functions (e.g., SSCC, JSC Crew Operations, ISS Payload Analytical Integration), which are not fully described.

Exhibit 4-1. Major POIF Functional Areas



Management. Management provides the overall direction of POIF as an organization. Because POIF is conducted with an integrated staff of NASA Government and contractor personnel, both Government and contract management is included. Currently this function includes all line management staff, administrative support, business and contract support, and staff for scheduling and metrics collection functions.

Operations Integration. The operations integration function includes the Payload Operations Directors (PODs) who direct the operations preparation activities for mission increments, as well as the PODs who operate in the POIC directing real-time payload operations activities on a 24-

hour-a-day, 7-day-a-week shift basis. This function also includes safety engineers, stowage engineers, and ground system integration engineers.

Lead Increment Scientists. The lead increment scientists oversee and coordinate all research activities during payload operations execution. They are provided by the ISS Program Office and report to the Research Planning Working Group (RPWG).

Planning. The planning function supports operations integration and execution by developing timelines for payload operations activities. Timelines vary from pre-increment on-orbit operations summaries (OOS), which establish at a daily/weekly level which payloads can be operated together, to short-term plans (STP), which are integrated SSCC–POIC products detailing daily ISS activities. The planning function requires the following:

- Collection of requirements from each payload developer that describes the activities required to operate that payload, together with the resources needed for each activity (e.g., crew time, power, etc.). Constraints on activities are also identified (e.g., predecessor activities). Payload Activity Requirements Coordinators (PARCs) are assigned to payloads by research discipline.

- Development of planning models. The payload requirements are translated into mathematical models used by the Payload Planning System to construct timelines.

- Development of OOS. Currently a baseline OOS and a final OOS are constructed for each increment. The OOS is used for advanced planning of payload operations, and by the payload analytical integration function to aid in evaluating payload compatibilities for manifesting purposes.

- Development of STP. Shortly before each increment begins, an STP is developed for the increment, and updated throughout the increment.

- Real-time support. A timeline change officer (TCO) is staffed 24 hours a day, 7 days a week in the POIC to evaluate and coordinate changes that occur in the timeline during real-time execution. Changes may be initiated by crew request or performance, by PI request, or by contingencies that occur during operations. The TCO is supported by the payload planning manager (PPM), timeline maintenance manager (TMM), and payload planning/scheduling engineer (PPSE) staff, who use the Payload Planning System (PPS) to evaluate changes and update the timeline. The support staff operates on a nominal 8-hours-a-day, 5-days-a-week basis.

Operations Control. The operations control function integrates the operation of payloads by their respective PIs, through the coordination and configuration of shared services necessary for experiment operation. Operations control manages and configures command system use to enable RPI and TSC commanding. Operations control also monitors, configures, and performs problem resolution for the PLSS. PLSS includes the EXPRESS Rack subsystems, as well as other laboratory support equipment (LSE). Operations control is responsible for managing all files uplinked to the ISS. The operations control function also operates payloads delegated to it, some of which support other experiment operations. An example is the Active Rack Isolation System (ARIS), which reduces microgravity perturbations within the rack environment but is also used for the ARIS-ICE).

The operations control function is performed principally in real-time operations, through the operations controller (OC), command procedures officer (CPO), the payload rack officer (PRO), and the payloads systems engineer (PSE) positions in the POIC. However, significant preparation work is required on a continuing basis to prepare for real-time operations. Preparation tasks include familiarization with new payloads and PLSS equipment, consulting with PIs on the operating plans for their payloads, and defining, modifying, and verifying POIC command and data displays.

Data Management. The data management function configures the payload components of the U.S. C&DH system to achieve data return in response to payload requirements. It also operates the ISS television systems, including the configuration and pointing of onboard cameras. Configuration and management of the KuBand system is particularly significant, because it is the main channel for return of payload data, television data, and onboard recorded data. The function also oversees operation of the POIC systems that collect and distribute data.

Data management is performed principally in real-time operations, through the data management coordinator (DMC) and photography and television operations manager (PHANTOM) positions in the POIC. The bandwidth integration timeliner (BANDIT) and weekly implementer of systems and resources for data (WISARD) positions also support the function on an 8-hour-a-day, 5-day-a-week basis. Operations preparation tasks include collecting data return requirements from the PIs, ensuring that payload data parameters are properly entered into the C&DH database, and providing scene definition for onboard television operations.

Crew Displays. The crew display function integrates and reviews PI requirements for onboard computer displays. The integration function involves collecting PI display designs and communicating them to ISS Program implementation functions, while the review function ensures that displays are functional from a crew and human factors point of view. The review function is performed against standards established by the ISS Program.

Payload Operations Data File (PODF). The PODF function is required to collect and review payload crew operating procedures, and to convert approved procedures into MPV format for uplink to the ISS. Procedures are reviewed against standards established by the ISS Program, and may be verified through interaction with the crew during training activities. The PODF function also is responsible for developing and maintaining procedures for PLSS and facilities assigned to the POIF (e.g., EXPRESS, WORF, ARIS, and MELFI).

The PODF is principally a pre-increment function, but also staffs a 12-hour-a-day, 5-day-a-week position in the POIC to process procedure changes occurring during on-orbit activities.

Training. The training function coordinates and integrates flight crew training for operating payloads. The function includes establishment with the PIs of training requirements and planned methods; collection, review, and in some instances preparation of payload training material; preparation of EXPRESS training materials; and coordination of the delivery of training to the flight crews. The function also includes management of training and simulations for ground support personnel, including POIF staff, TSCs, and PIs.

The training function is performed primarily pre-increment, but because of the familiarity of training personnel with both specific flight crews and crew operations, the training function staffs the payload communicator (PayCom) position in the POIC during on-orbit operations. The

PayCom is responsible for effective communications among all payload ground staff and the crew.

4.1.1.1 POIF Operations Preparation Schedules

Current POIF operations preparation schedules for an increment are shown in Exhibits 4-2 and 4 3. The lead times for products have been reduced, and POIF continuous improvement activities are seeking to further reduce lead times.

Exhibit 4-2. User Input Summary

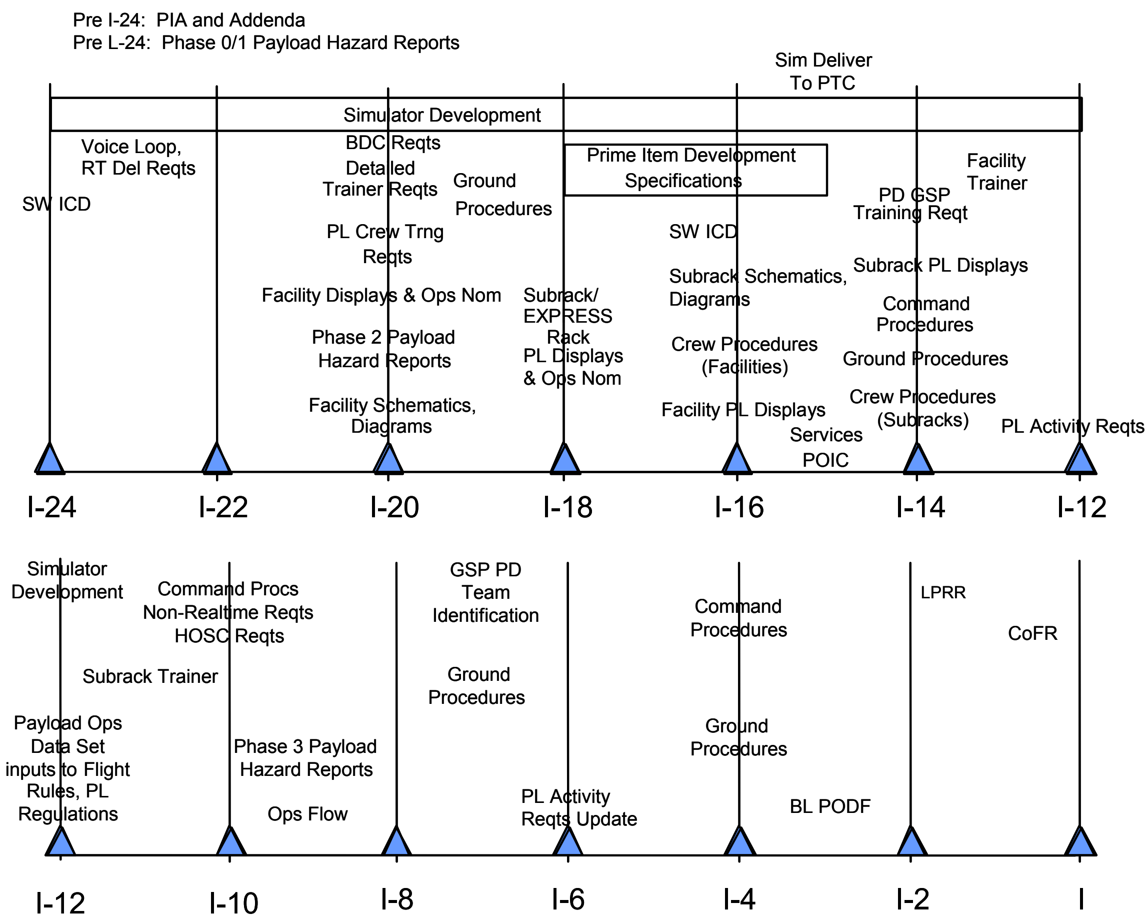


Exhibit 4-3. Generic Schedule Roll Up (1 of 2)

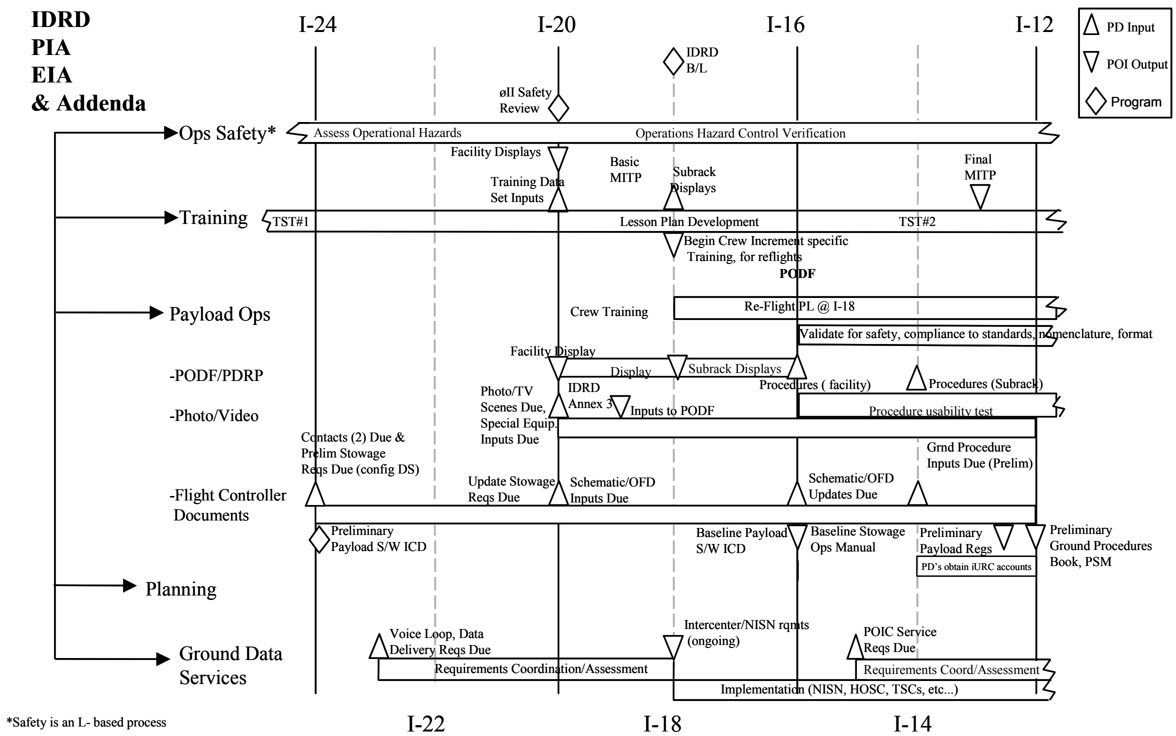
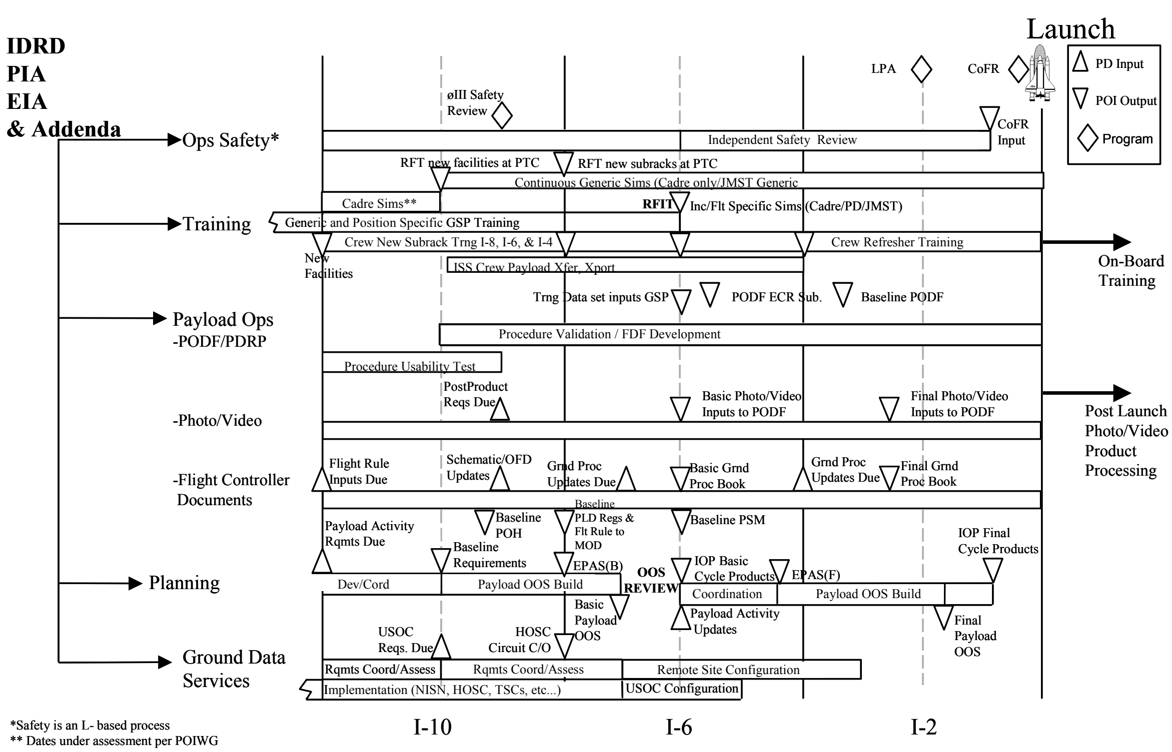


Exhibit 4-3. Generic Schedule Roll Up (2 of 2)

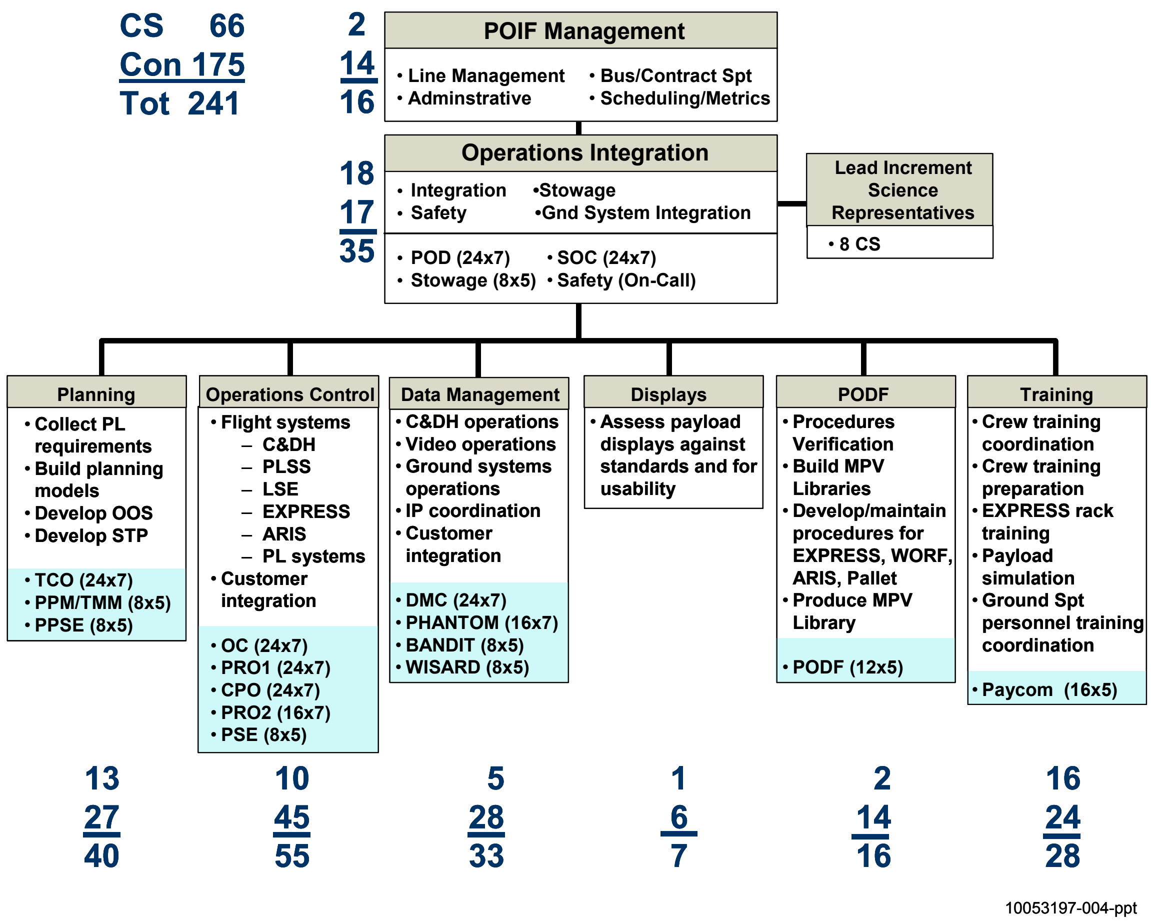


Although some activities begin as early as 36 months before the increment, the majority of the work occurs within the 12 months prior to the increment. Early activities include, importantly, consulting with PIs to establish with them the requirements and strategy for operations preparation. Ground system communications requirements and training preparation are also long-lead items.

4.1.1.2 POIF Labor Resources

The POIF is a labor-intensive activity, assisted by tools created internally to the POIF or provided by the POIC. The current POIF labor staffing is shown in Exhibit 4-4.

Exhibit 4-4. Current POIF Functions and Staff



The current distribution of POIF manpower against categories of activities is shown in Exhibit 4-5.

The distribution of labor is shown further in Exhibit 4-6, converted to LOE.

The current manning of real-time POIC positions is shown in Figure 4-7.

Exhibit 4-5. FY 2002 POIF Manpower

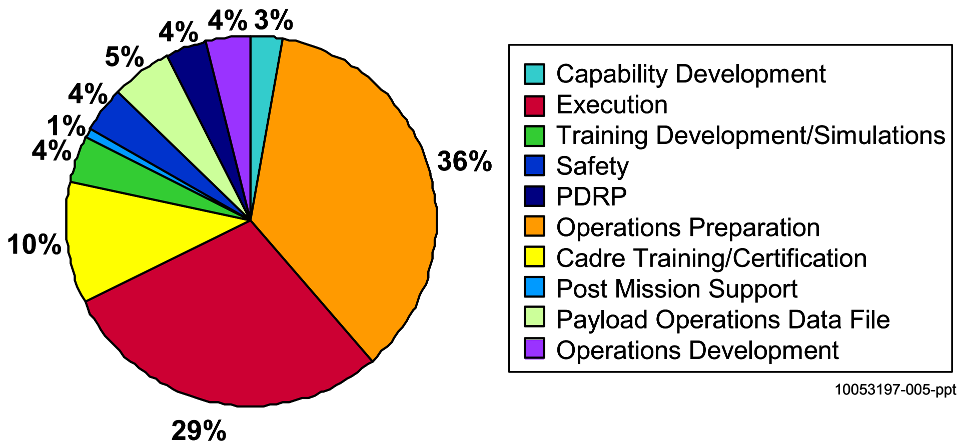
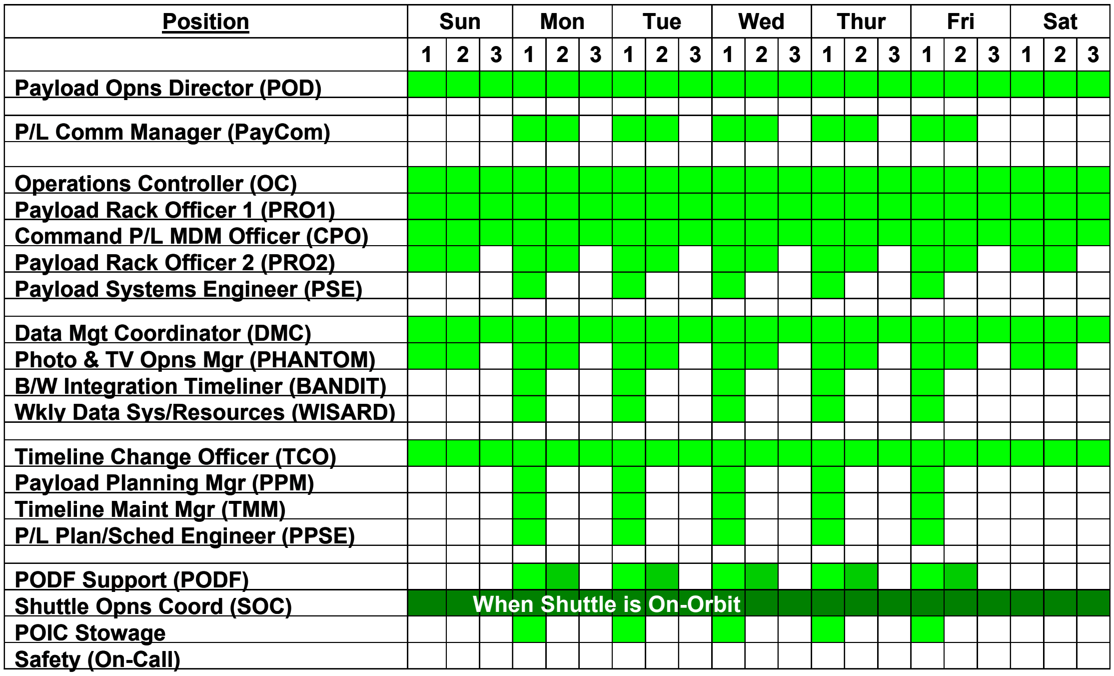


Exhibit 4-6. FY02 Manpower Distribution

	Percentage	FTE
Operations Preparation	36	87
Operations Execution	29	70
Capability Development	3	7
Training Development/Simulation	4	10
Safety	4	10
Payload Display Review Panel	4	10
Cadre Training/Certification	10	24
Post Mission Support	1	2
Payload Operations Data File	5	12
Operations Development	4	10
Total	**100**	**241**

Exhibit 4-7. POIF Real-Time Positions



4.1.2 General POIF Findings

Provides Essential Functions. The Study Team assesses that the POIF is providing essential payload operations functions, not otherwise performed, which include the following:

- Integrating ISS payload operations
- Facilitating the performance of experiments by PIs and crew, and managing shared resources
- Controlling the PLSS (KuBand data, MCOR/HCOR, PL MDM)
- Controlling assigned onboard research facilities (8 EXPRESS Racks, MELFI, ARIS, and WORF)
- Ensuring the safety of payload safety-critical operations

Steep Learning Curve. Current POIF implementation is successfully enabling the manifested research in parallel with assembly operations and has achieved a steep learning curve and cost reduction in the first year of operations.

- Preliminary OOS has been eliminated (12 to 18 months before increment)
- Real-time positions have been reduced
- PODF staff now formats crew procedures, rather than PDs (PODF staff reduced 33 percent)
- PDRT now works with PDs earlier to familiarize and guide display development (PDRT staff reduced 57 percent)

- Training, PODF, and PDRP functions have been integrated
- Training and simulation requirements have been reduced (training/simulation staff reduced 27 percent)
- Increment preparation schedule template has been shortened
- Payload Operations Integration Working Group (POIWG) was established to increase face-to-face interaction with PDs, shorten time templates, and increase process flexibility for payloads

The POIF Team is pursuing additional areas for savings:

- Continuous assessment of cadre positions to develop efficiencies and reduce real-time staffing
- Reductions in travel by locating personnel at JSC and KSC
- Better allocation of payload time, enabling staffing of positions only when needed
- Scaling back the CoFR process to include only safety and interface items

Workload Factors. The Study Team recognizes that current workload is significantly driven by operations workarounds and frequent changes due to assembly configurations, constraints, and manifest. Also, the initiation of IP payload operations in 2004 will create a workload to define and verify the interfacing procedures beginning in 2003. An added learning curve must be expected with associated workload as IP operations begin.

PI/PD User Community Observations. The current PI/PD user community evaluates current payload operations as too complex and too cumbersome. This response occurred consistently in the POCAAS survey of researchers (see Section 2.4). Some relevant observations included the following:

Some of the researchers evaluate their effort required for ISS payload operations as two to four times greater than for the same or similar Shuttle/Spacelab payloads:

- "Differing standards, competing committee structures, changing requirements"
- "….requirements can be trimmed…."
- "…verification for non-critical requirements is ridiculous…."
- "…current ISS document burden is greater than for Spacelab….multiple documents or databases…requests for identical data in multiple places…then not used in real time…"
- "…not so much the number of approval levels as the number of points of contact…"

Need for Reengineering. The Study Team believes that the ISS Program, including POIF, needs an increased focus on finding new, simpler, less expensive processes, rather than just improving current processes. This means reduced requirements and documentation, better coordination and less overlap among functions, and greater reliance on competent but fewer people operating with less formality. The Team believes *strongly* that the necessary process and documentation reform must be accomplished at the payload integration level, not just within payload operations.

4.1.3 POIF Cost-Reduction Options

The POCAAS was established primarily to seek ways of reducing the cost of payload operations, from the perspective of an experienced Team external to NASA. The Team was also charged at the beginning of the study to seek innovative changes in architecture and concepts, as opposed to a detailed audit of current processes.

The Team, in assessing POIF, considered two approaches:

1. Conduct a detailed review of current requirements, processes, and standards to seek efficiency improvements. Incremental cost reductions would be identified against specific program changes.
2. Perform a bottoms-up estimate for a minimum, technically acceptable level of POIF, based on the assumption of basic operations principles and methodology, but assuming reasonable reduction of current program requirements and streamlining of current processes.

The Team selected Approach 2 as the most effective way to address the POCAAS charge. The Team believed that this approach would present the most innovative result and identify a minimum level at which, in the judgment of the Team, POIF could be successfully performed. This approach is consistent with the NASA direction at the beginning of the study to focus on concepts, not a detailed audit of current operations.

Approach 2 identifies the results potentially achievable by reengineering the POIF, as opposed to continuous improvement. The Team recognizes the ongoing continuous improvement efforts of the POIF team, as well as the ISS Program, and did not wish to duplicate those efforts. Within the time and resources available for the POCAAS, the Team does not believe they could acquire the detailed knowledge of the current performing organizations and better their continuous improvement results. However, the Team does believe that they present in this report a different perspective on POIF with potential cost reduction.

Caveat. Budget reduction based on this study must be accompanied by real changes in ISS Program requirements, processes, and standards, or ineffective payload operations will result.

The cost reduction option presented in the following analysis requires significant changes in requirements, processes, standards, and policies. Some of these changes are within Code U authority, some within ISS Program authority, and some require changes to policies that are institutional in nature.

The changes identified may result in increased but reasonable risk of crew and ground error with the result of a limited reduction in utilization efficiency. The Study Team believes that the increase in researcher satisfaction and reduction in cost greatly outweighs this risk. Some of the changes in reducing POIF cost could result in increased PI/PD workload and, therefore, should be subject to tradeoff to achieve reduction in total cost. In this regard, some may be applicable to classes of payloads, but not all payloads.

Some of these changes have been proposed individually during previous budget reduction exercises, and rejected as inappropriate within the prevailing program framework. That does not negate their reconsideration in the POCAAS, nor their acceptability in a different framework.

Recommendation. Budget reduction should be preceded by a definitive program action, working with the research community, to identify and define specific changes to reduce requirements, reduce complexity, increase flexibility, and reduce cost.

4.1.3.1 Concepts for POIF Cost Reduction

The Study Team began its assessment of POIF with the identification of a number of concepts for improvement in cost effectiveness.

- Consolidate payload operations requirements and standards, to the maximum extent possible, into one reference document. The composite set of requirements can then be managed more effectively than in multiple separate documents with separate approval channels. Requirements and standards should also recognize the diversity of payloads and offer flexibility for different classes of payloads.
- Focus the review of compliance with requirements and standards on the intent of the specification, and trade rework to meet requirements against the cost of strict adherence. Use standards as guidelines, rather than mandatory criteria. So long as safety of operation is not affected, delegate the interpretation and decision authority for acceptable compliance to the working level.
- Reexamine historical operations policies, which are largely based on sortie-mode operations (Shuttle and Spacelab), for applicability to ISS as a continuous research facility. Relax nonsafety criteria, optimizations, and constraints.
- Accept lower efficiency of payloads operations if necessary to reduce cost, while still working to improve efficiency over time. Accept increased risk to individual payload success on a given increment, while using continuing operation and reflight to increase research success in the longer run.
- Limit changes and recognize the cost of changes in allowing them (e.g., late changes in manifest, crew preferences).
- Reduce nominal POIF service levels to PIs/PDs. This may result in an increased burden on the PIs/PDs that increases total cost; therefore, provision should be made for exceptions, on an added cost basis, where PIs/PDs request assistance. Reduced service levels during real-time operations may result in a slower than desired response to payload problems or changes.
- Reduce lead times for products and activities as much as possible to reduce rework. Later lead times can allow more mature products from PIs/PDs in consideration of their development schedules, as well as minimizing impacts of late manifest changes.

4.1.3.2 Continuous Flow Concept

The Study Team observes that the ISS Program currently plans and executes operations as *increments* and *flights*, which are both essentially sortie modes. The crew is exchanged on an increment basis, and some planning and preparation takes place on that basis (e.g., the OOS, manifest selection, crew training). However, increments vary in length, and may be extended in length over time.

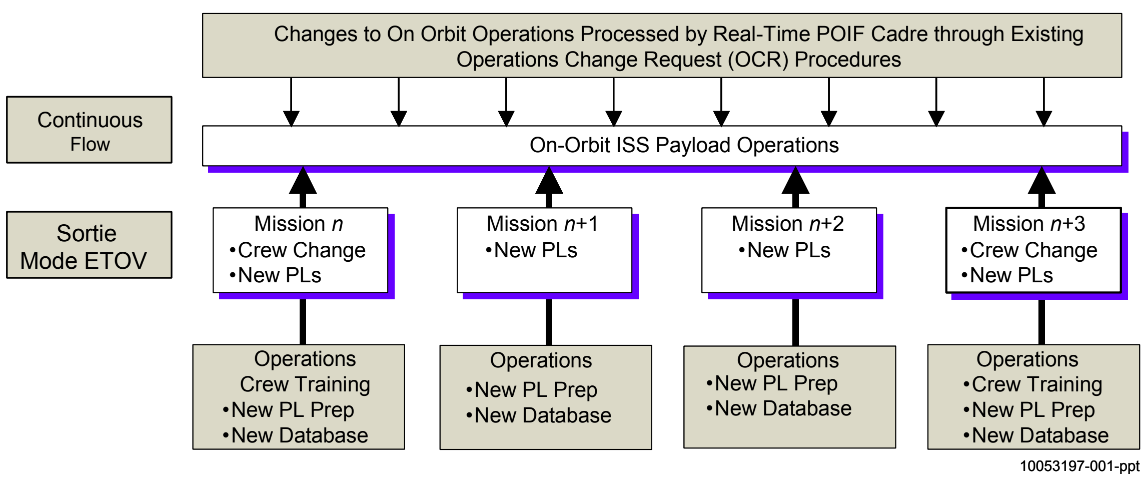
Payloads are manifested on ETOV flights, but some payloads continue operation across flight and increment boundaries. Telemetry and command databases change on a flight basis, requiring changes in onboard and ground displays and systems. Flight readiness review is accomplished on a flight basis. Because operations preparation is driven by the payload manifest, it is driven primarily by flights.

The Study Team observes that existing ISS processes and standards incorporate sortie mode policies. For example, the Payload Integration Process Improvements briefing to the ISS Independent Review (IIR) noted the following:

- "The PIA Addendum for each increment contains ascent and descent requirements and on-orbit resource requirements"
- "Because the ISS will use many aspects of the data collected for multiple increments, detailed standards have been established to ensure the usability of the products from one flight and crew to the next"
- "Flight products in the past have been tailored to the specific crew and reworked for the next flight"
- "Compared to Shuttle there are additional requirements and some that have become more strict…..driven in part…by the need to optimize the crew interface…."
- "The ISS integration template is driven by the ISS crew training template…the ISS template is longer by about three to six months"

The Study Team adopted the concept of *continuous flow*, as illustrated in Exhibit 4-8.

Exhibit 4-8. Continuous Flow Concept



Under the continuous flow concept, on-orbit operations are managed to the maximum extent possible as a continuous flow, using existing real-time staff and operations change request procedures in lieu of separate readiness reviews, control boards, and documentation. All changes in procedures and plans for payloads already on-orbit are managed through the OCR process. This will maximize productivity of the staff required to be on duty to manage real-time activities. The real-time staff can be supplemented during peak periods of change activity as needed.

Planning and preparations for logistics flights continue as a batch process, using off-line POIF staff. These preparations include procedures, displays, training, and PODF for new payloads which have not flown before, and for reflight payloads which have changed significantly since their previous flight. Long lead planning for new payloads and activities necessary to assess manifest compatibility are also conducted in this manner.

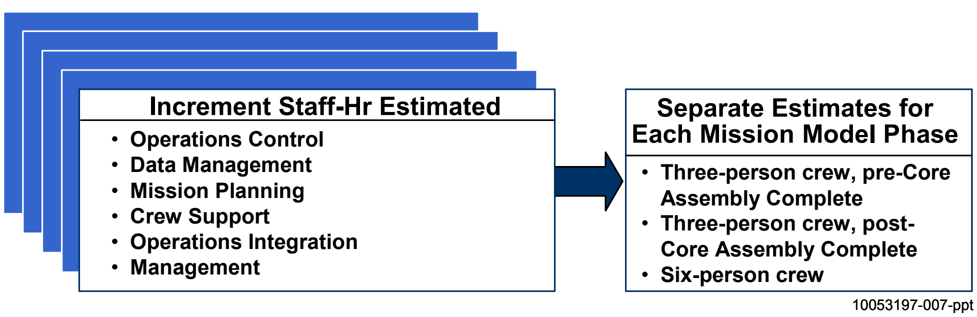
POIF staff members continue to be rotated between on-console shift duty in the POIC and off-line office support to maintain continuity and consistency in operations, and (importantly) to reduce the impact of shift work on the staff.

4.1.3.3 POIF Independent Cost Estimate Methodology and Assumptions

Applying the concepts identified in Sections 4.1.3.1 and 4.1.3.2, the Study Team performed a bottoms-up, minimum-service-level cost estimate. The cost estimate assumed the Mission Model described in Section 3.2.1, and that the minimum service level was appropriate for simple and average payloads, under the definitions in Section 3.2.1. The estimate assumed that optional additional POIF assistance could be made available at added cost. The PD would negotiate and fund added cost services at the time the planning for a payload began. Added cost services would be required for complex payloads and as optional assistance at PI/PD request.

Labor staff-hours for each of the basic POIF functions was estimated by week for a single 3-month increment as illustrated in Exhibit 4-9, time phased over 24 months, and assuming the payload complexity mix defined in the Mission Model.

Exhibit 4-9. Cost Estimate



Overlapping Increment Preparations Summed

This process was repeated to provide separate estimates for each of the program phases defined in the Mission Model:

- Three-person crew, pre-Core Assembly Complete
- Three-person crew, post-Core Assembly Complete
- Six-person crew

For each of the program phases, the individual increment estimates were then overlaid and summed to account for overlapping increment preparations. Level-of-effort estimates were also included for continuing activities in each POIF function that are required independent of increment activities.

The estimates made no distinction between Federal Government and contractor personnel, but only estimated labor hours required to perform work. The Study Team acknowledges that some additional overhead may be associated with the division of work between Government and contractor, but expects all staff to work as an integrated team.

Subteams of the POCAAS Study Team were established as shown below to perform the cost estimation.

- Planning – Jerry Weiler and Ed Pavelka
- Management, Operations Integration, and Operations Control/Data Management – Tom Recio and Fletcher Kurtz
- Crew Support – Chuck Lewis, Bob Holkan, and Ron Parise

The subteams based their estimates on the review of ISS Program presentations and documentation, the POCAAS Mission Model (Section 3.2.1), the concepts described in Sections 4.1.3.1 and 4.1.3.2, discussions with MSFC and JSC operations personnel, and their own expertise. Each subteam member has had years of prior experience in planning, performing, and managing the same functions for ISS and predecessor programs.

The entire Study Team reviewed and endorsed the subteam estimates.

Key factors in the basis of estimate for each functional area are summarized in the following paragraphs.

Operations Control/Data Management

Assumptions:

- Three increments in preparation and one increment in real-time support continuously (3-month increments)
- Data collection and preparation for an increment begins about 12 months before the increment, with majority of work performed during the last 6 months
- Systems and process development rework, when needed, begins 18 months prior to increment
- PLSS configuration stable after Core Assembly Complete
- KuBand communications coverage increased and stabilized after 2003
- Processes are stable and documented for three-person crew pre-assembly complete
- Use of on-the-job training is maximized using real-time slack time
- Reduced requirements, reviews, control boards, and documentation

The analysis found the workload to be not directly a function of the number of payloads or the complexity of the experiments. The magnitude and complexity of the ground support OC/DMC tasks is primarily a function of the composite payload increment integrated tasks, including OC/DMC requirements for PLSS support, television downlink/real-time support required during AOS, television scene setup and execution, command loads and verification and uplink sizes, recorder management and data distribution, integration of crew/telescience, and most importantly, the iteration of the above tasks during preincrement preparation and real-time. The labor estimate was assessed task by task based on the integrated payload compliment, and a separate payload data-gathering, maintenance, and consolidation preparation task (customer integration) was assessed experiment by experiment and summed with the integrated tasks described previously.

The estimate includes 10 percent of the operations preparation work done more than 12 months prior to increment, 30 percent done between 6 and 12 prior to increment, and 60 percent done within that last 6 months prior to increment.

The following risks are associated with the estimate:

- Limited service levels may impact smooth integration of IP payload operations during the transition
- Lengthened response to problem correction may result in loss of research efficiency

Planning

Assumptions:

- Increments are 3 months in duration, which implies that four increments are always in work simultaneously.
- Data collection for an increment begins 12 months prior
- Only one OOS is produced for an increment. This is delivered 2 months prior to the increment. The OOS planning level (complexity) is reduced wherever possible.
- Use of a typical (as opposed to specific) increment template for payload analytical integration analyses for assessing manifest compatibility.
- No special timeline development or planning for cadre, payload analytical integration, training, or simulations; prior operational or generic timelines used
- Manifest fixed at I-12 months; minor changes accepted at I-6 months
- Late manifest changes accepted on nonoptimized activity insertion basis only.
- Planning procedures stable after 2004.
- Reduction of program requirements and process flow documentation
- Training is accomplished on the job.
- A continuous operations flow concept is implemented.

In the analysis, the payloads in the Mission Model, including the continuing and reflight portion drove the Payload Activity Requirements Collection (PARC) and the pre-increment planning (OOS development) manpower. The lead-time and manpower were reduced due to the assumption of a single OOS. The Mission Model (both the number and complexity of payloads) also drove the number of pre-increment planners required. When the IPs where added, additional planning manpower was added to account for the integration of their payload timelines into the overall integrated station payload timeline.

The TCO position was reduced to 16 hours a day from 24 hours a day, seven days a week, under the philosophy of addressing problems on the day shift, as opposed to before the next crew awake shift.

The risk identified with the estimate is that the less optimized planning may result in a less timely research efficiency/accomplishment, but over time, with the continuous flow concept, the research will be accomplished.

Crew Support

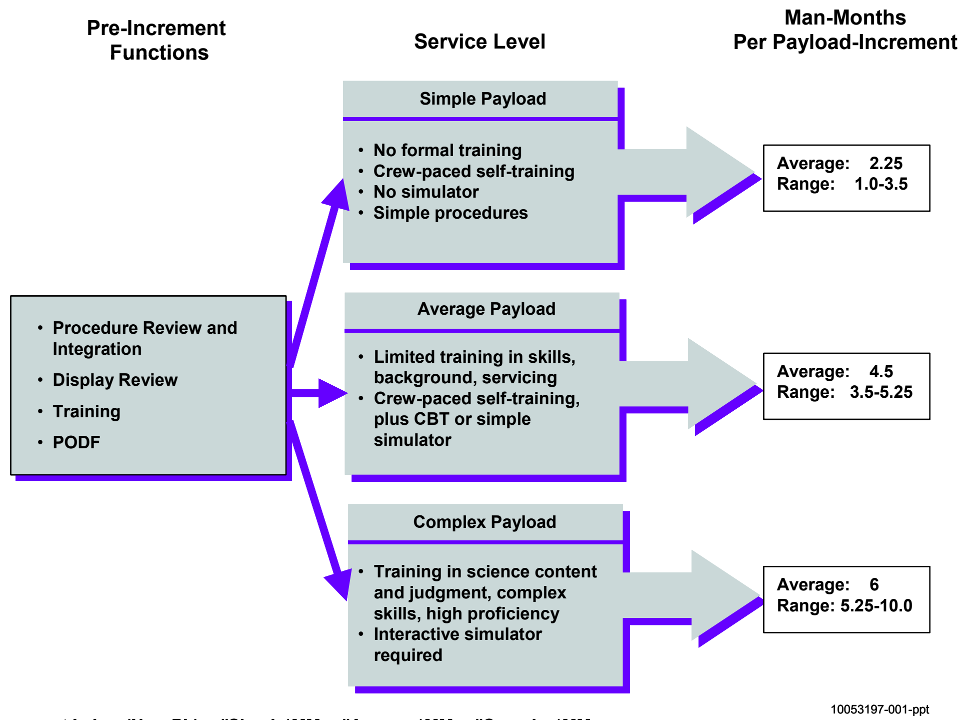
Assumptions:

- All functions described by MSFC in the Payload Operations Presentation to the POCAAS, November 13, 2001, for the Training Team, Payload Operations Data File Team, and Procedures/Display Review Panel must be performed
- Crew training is performed at the Payload Training Complex at JSC
- Manpower required to perform the POIF preparation functions (planning, coordination, facilitation, evaluation, training delivery) is directly proportional to required crew involvement for each payload, as reflected in complexity classifications
- A small amount of manpower is used to identify and categorize payloads early in the process flow; simple payloads then require little involvement later, and thus little or no manpower for some functions
- A fixed level of manpower is required for administration, coordination, and instructors located at JSC
- Reflight of a payload requires less manpower than the first flight; procedure and display changes are made only to fix operational problems (no personal preference changes)
- PD writes procedures to ensure proper operation and assumes risk for poorly written procedures
- PD designs displays to operate the experiment efficiently and assumes risk of poorly designed displays
- The exact same "look and feel" of procedures and displays among different experiments are not required; PD accepts risk of any inefficient experiment operations that may result from not fully meeting standards
- PD provides training to first-time crew; subsequent training is delivered by POIF staff

Crew support, more than other functional areas, is driven by the number of payloads and payload complexity. A time-phased crew support preparation estimate was performed for a "typical" payload in each of the three complexity levels (simple, average, and complex) defined in Section 3.2.1. A number of current payloads were evaluated in formulating the typical estimate. The resulting "typical" simple, average, and complex labor profiles were then summed for an assumed increment payload complement, based on the POCAAS Mission Model. Overlapping increment labor profiles were then summed to generate labor estimates for the three mission phases (three-person crew pre-AC, three-person crew post-AC, and six-person crew). A fixed LOE was added for management, administrative support, and other sustaining functions. The LOE crew support tasks that are not driven by the payload model were assumed to be stable after 2003.

The bottoms-up estimates were also used to generate the summary crew support parametric model illustrated in Exhibit 4-10.

Exhibit 4-10. Crew Support Parametric Labor/Payload Model



Increment Labor (New PL) = #Simple*MM + #Average*MM + #Complex*MM
Increment Labor (Reflight) = 0.4*(New PL)
Fixed LOE = 9

The risk associated with the reduced crew training model under this estimate is operations delay or crew error, which may reduce research efficiency.

Operations Integration

Assumptions:

- Procedures are stabilized after Core Assembly Complete
- Specialists (safety, stowage) provide support across all increments
- A payload operations director leads the preparation for each increment
- Flight-qualified PODs lead multi-increment integration tasks and reviews
- Payload operations directors lead real-time support on a 24-hours-a-day, 7-days-a-week basis

- Workload will move rapidly toward continuous process, rather than batch (increment) process
- Reduction in program requirements, reviews, and control boards

The operations integration workload was judged relatively insensitive to the number of payloads supported per increment but is driven by the number of interfaces and ongoing activities requiring coordination. The estimate requires the following:

- Five payload operations directors for real-time 24-hours-a-day, 7-days-a-week operations
- Four shuttle operations coordinators (SOC) for 24-hours-a-day, 7-days-a-week real-time support while the Shuttle is on-orbit, SOCs also perform premission planning and preparation for flights
- Three PODs for coordination of pre-increment preparations
- Two PODs for coordination of IP activities, plus one operations engineer
- Five safety engineers
- Three stowage engineers
- Two scheduling/integration and two ground support engineers
- Two project management and PCB/MCICB support engineers

The estimate assumes that Operations Integration staff are rotated among the on-console POD positions and other integration tasks, both to promote continuity and integration of activities, and to provide relief to shift work. The labor estimate is based on estimated work, not on the number of staff having the title "Payload Operations Director."

The principal risk in the estimate is that IP interface procedures and reviews are not yet fully defined, resulting in workload uncertainty.

Management

Assumptions:

- Line management is estimated within functional areas
- Scheduling is performed in operations integration
- Industry norms for management of 100 to 150 LOE services contract

The analysis estimates the following:

- Two senior managers (one Government and one contractor)
- Two LOE of administrative support
- One contractor LOE of business/contract support, based on industry norm for approximately 150 LOE services contract
- Two staff LOE for reporting and management support

4.1.3.4 Summary of Minimum Service Level Cost Options

POIF Cost Option 1. The results of the POCAAS independent cost estimate for a minimum acceptable level of POIF support are summarized in Exhibit 4-11.

Exhibit 4-11. Minimum Service Level Cost Option (LOE/year)

	Current	POCAAS Bottoms-Up Estimate		
Function	**3 Crew, Pre-AC**	**3 Crew, Pre-AC**	**3 Crew, Post-AC**	**6 Crew**
POIF Management	16	7	7	7
Operations Integration – RT	10	9	9	9
Operations Integration – Prep	25	19	20	20
Planning – RT	10	7	8	9
Planning – Prep	30	16	20	21
OC/DMC – RT	28	28	35	35
OC/DMC – Prep	60	36	43	46
Crew Support – RT	9	9	9	9
Crew Support – Prep	53	27	31	55
Total	**241**	**158**	**182**	**211**

The labor estimate is total LOE, including both Government and contractor. The estimate assumes the POCAAS Mission Model, the concepts discussed in Sections 4.1.3.1 and 4.1.3.2, and the further assumptions described in Section 4.1.3.3.

It is essential to recognize that the concepts included require an ISS Program-wide streamlining of requirements, processes, standards, and documentation to be successfully accomplished. POIF will not be able to achieve this level of operation independent of change in other program functions. Achievement of POIF cost reduction under this model is directly dependent upon ISS Program determination and decisions to accept performance risk and accomplish changes in current requirements, policies, and practices.

POIF Cost Option 2 – Elimination of SFOC Training Instructors. Current crew training plans require the POIF to integrate the training products and their initial delivery, but for repeating payloads, plans required the POIF to hand the delivery over to the SFOC contractor in the Payload Training Facility. This handover has not yet taken place. POIF Cost Option 2 eliminates this SFOC function and continues with the current practice of POIF and PI/PD staff delivering the training. The POIF Cost Option 1 estimate includes the total labor required.

POIF Cost Option 3 – PI/PD Assistance. The PIs/PDs vary in their experience level with human space operations, especially if they are first-time users. POIF assistance to inexperienced PIs/PDs in the past has reduced development time, reduced overall cost, and resulted in better operations products.

This cost option would provide a staff of 10 to 15 operations interface engineers in the POIF to work with PIs/PDs on an as-requested basis to assist them. (The number of staff should be based on current payloads in process and their needs). This approach can allow the PIs/PDs to focus on their core competencies of science research and experiment development, while using experienced operations personnel to translate experiment data into operations products and formats.

The operations interface engineers, if maintained in a separate pool within the POIF, can provide an added role of advocacy for continuous improvement of the researcher interface within the POIF.

POIF Cost Option 4 – IP Operations Interface Preparation. Limited process and procedural definition has been accomplished to date for IP payload operations interfaces. A dedicated team of 5 to 6 operations personnel is needed in 2003–2004 (or beginning approximately 2 years prior to Columbus/JEM on-orbit delivery) to work with the PCCs to develop interfaces. Some additional resources may be required in 2004 (or beginning approximately 1 year prior to Columbus/JEM on-orbit delivery) for joint simulations to validate procedures and train IP personnel. The resource level needed is dependent upon SSCC simulation plans.

Implementation Considerations

A balance should be maintained between Government and contractor staff. The Government component is essential because of NASA's responsibility and to maintain a core skill base. The POIF Contract (NASA-50000) ends in FY 2005, and a recompete is assumed to take place in FY 2004.

Capability must be kept to rotate staff between on-console real-time shifts and preparation work performed in the normal office work environment. This rotation is essential for staff retention and maintenance of skills.

A phase-in of the POCAAS minimum service level model is required to accomplish changes in current requirements, documentation, and operating practices, and to avoid disruption to ongoing payload operations. A recommended phase-in profile is shown in Exhibit 4-12. The profile reflects a transition in FY 2002–2003 to the Minimum Service Level Model. A transition from the three-person crew, Pre-Core Assembly Complete payload traffic model (30 payloads/increment) to the higher three-person crew, Post-Core Assembly Complete payload traffic model (40 payloads/increment) begins in FY 2005, based on the POCAAS Mission Model. Although IP payload operations may begin in FY 2005, the total payload workload does not change until FY 2006. The additional initial effort required for integration of the IPs into payload operations is separately accounted for in Option 4. The transition to the six-person crew payload traffic model (70 payloads/increment) begins in F2008.

The assumed Government staff level in FY 2003 and subsequent is an arbitrary fraction of the total staff.

4.1.3.5 POIF Recommendations

POIF Recommendation 1 – Minimum Service Level. The Study Team recommends that POIF Cost Option 1 be adopted, with an appropriate phase-in, and conditional upon similar ISS Program changes in payload integration that are necessary for the success of this option.

Exhibit 4-12. LOE Phasing for POIF Cost Options

FY	02	03	04	05	06	07	08		10	11
Cost Option 1										
Government	66	58	50	50	50	50	50	50	50	50
Contractor	175	142	108	120	132	132	147	161	161	161
Cost Option 3										
Contractor		15	15	15	15	15	15	15	15	15
Cost Option 4										
Contractor		5	5							
Total	**241**	**220**	**178**	**185**	**197**	**197**	**212**	**226**	**226**	**226**

POIF Recommendation 2 – Elimination of SFOC Training Instructors. The Study Team recommends that this option be adopted. A level of SFOC funding must be maintained for PTC maintenance support.

POIF Recommendation 3 – PI/PD Assistance. The Study Team recommends that POIF Cost Option 2 be also adopted, subject to a review of the planned payload manifest and the needs of manifested PIs/PDs.

POIF Recommendation 4 – IP Operations Preparation. The Study Team recommends that POIF Cost Option 3 be reviewed with respect to IP agreements, processes, and timing. Timely preparations for IP payload operations are essential to avoid disruption and loss of science return.

4.2 Payload Operations Integration Center

4.2.1 Current POIC Description

The POIC is the facility located at MSFC that houses the central information technology infrastructure for payload operations, and hosts the POIF and the U.S. Operations Center (USOC).

The USOC is a portion of the POIC that provides floor space with access to POIC services for PIs who may wish to operate their ISS payloads from that location.

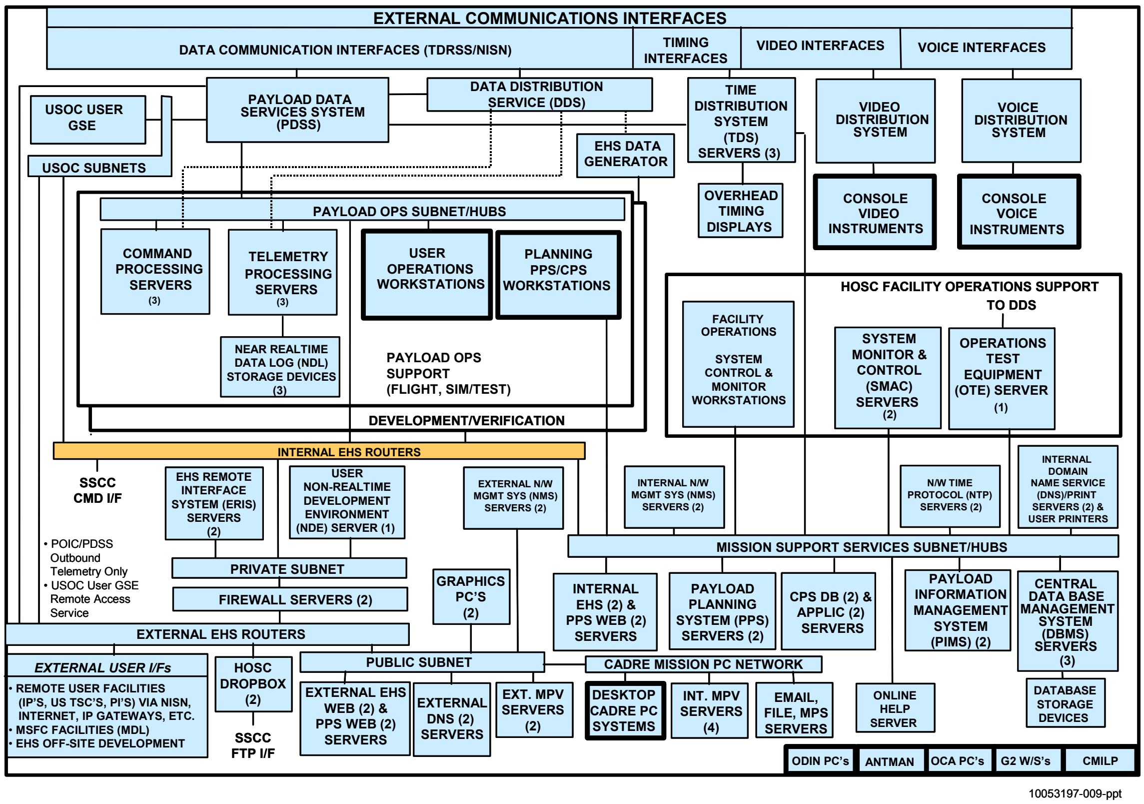
The POIC performs the following functions:

- Real-time (RT) and near-real-time (NRT) telemetry processing
- Command processing
- POIC and remote command and display processing
- KuBand data distribution via the Payload Data Service System (PDSS) to the Internet
- Local and remote voice communications (HVoDS/IVoDS)
- Local video distribution

- Hosting of operations tools
  - Payload Planning System (PPS)
  - Payload Information Management System (PIMS)

A schematic of the POIC information systems is shown in Exhibit 4-13.

Exhibit 4-13. POIC Schematic



The system is relatively complex, due to the multitude of services provided. The system is also highly distributed, due to its design in the early 1990s based on Unix server technology prevalent at the time. The system is highly capable and flexible, providing a variety of services and features.

The system includes about 150 workstations that are used principally by POIF operations personnel. The system also supports remote users at the TSCs and at RPI locations. Portions of the system are designed to support up to 300 simultaneous remote users.

4.2.2 POIC Cost Elements

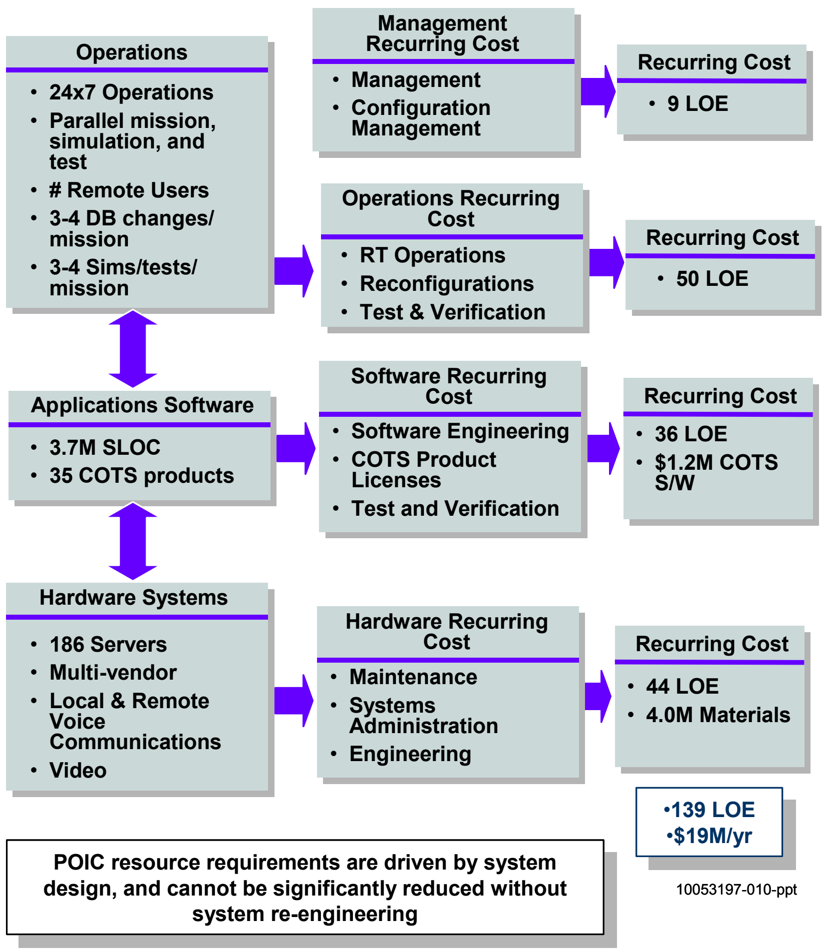
The POIC cost elements are shown in Exhibit 4-14.

The Hardware Systems hosts 3.7 million source lines of code (SLOC) of custom applications software, which perform the functions shown above. The software was designed to reduce custom code through the use of commercial off-the-shelf (COTS) products and contains 35 commercial software products.

The operations staff is responsible for conducting 24-hours-a-day, 7-days-a-week operations of the systems and supporting in parallel the real-time ISS mission, including Shuttle data processing; mission simulation; and information systems test, both internal and with external locations.

The recurring costs are driven largely by the system design—the large number of servers that must be maintained and configured, the quantity of COTS software licenses, the amount of custom code that must be maintained, and the resulting operational complexity. The operations staff is also driven by the operational workload, i.e., the number of parallel simulations and tests.

Exhibit 4-14. Current POIC Cost Elements (Pre-FY 2002 Budget)



4.2.3 General Findings

POIC Status. The POIC development was essentially completed within the past year, although the last developmental software delivery is scheduled for second quarter of CY 2002.

In parallel with completion of development, the POIC has undergone a staff reduction from 250 LOE in March 2001 to about 140 at the time of the POCAAS study, with a further planned reduction to 125 in March 2002.

The Study Team observes that systems of this type typically require approximately a year to stabilize their configuration, software, and operation after development is complete. The POIC is still in this shakeout period.

Need for Technology Refreshment. The Study Team observes that technology refreshment is essential to reducing POIC recurring cost as well as maintaining system effectiveness. Some POIC equipment (e.g., SGI Indy workstations, SGI Challenge Servers) are at or nearing end-of-life and/or economical operation. Newer technology would allow system consolidation and lower maintenance and operating cost. Simplification of the system and increased automation of operations is also essential to reduce labor cost. However, the necessary reengineering, software migration, and hardware replacement requires an investment to accomplish.

FY 2002 Budget. The FY 2002 POIC budget guidelines require an immediate and continuing 10 percent reduction in annual operating cost. MSFC responded to these guidelines with a request for an increase of $3.5 million in FY 2002–2003 funding to enable reengineering to achieve the 10 percent reduction in the out-years. MSFC proposed four initiatives to achieve this reduction:

- Consolidation of the command, telemetry, and database server functions onto new SGI clustered servers, with an FY 2002 hardware buy
- Migration of the workstation command and display functions from the current SGI Indy workstations to PCs
- Reengineering of the PDSS to consolidate servers and replace the custom CCSDS packet processing hardware with a general purpose system
- Simplification of PIMS and removal of the expensive In-Concert COTS software

MSFC also provided a budget alternative that would meet the FY 2002 budget guidelines without over-guidelines in FY 2002–2003, but with significant impacts and risk. Measures proposed to allow this would include operating without vendor maintenance for several years and a moratorium on any functional software changes, until the resources thus freed could be used to reengineer the system and migrate the software to Intel-based servers with a Linux operating system.

MSFC did not address means of further cost reduction beyond the FY 2002 guidelines.

4.2.4 POIC Cost Reduction Option

The Study Team reviewed and updated the POIC Ground Data Systems Independent Assessment previously performed by Fletcher Kurtz in support of the MSFC Ground System Department. This updated assessment identifies a variety of actions to reduce POIC recurring cost.

- Consolidate server functions on new technology systems that afford significantly greater performance at reduced acquisition and operating cost
- Provide sufficient robustness and reserve capacity to allow maintenance on a nominal 8-hours-a-day, 5-days-a-week basis
- Migrate display functions from Unix workstations to PCs
- Perform software migration in a way that provides future portability across platforms

- Adopt a software productivity improvement program in accord with the Software Engineering Institute standards. This methodology has been shown to achieve a 15- to 21-percent reduction in effort for a one-increment change in the Software Process Maturity Level. The POIC contractor does not currently have such a program.
- Reengineer PDSS to consolidate servers and replace the custom CCSDS packet processing hardware with a general purpose system.
- Simplify PIMS and remove the expensive In-Concert COTS software
- Reengineer PPS to simplify operation, provide better integration with CPS, and eliminate at least the DEC server currently in use for data management timelining.
- Reengineer operations processes to take advantage of the system consolidations, and to provide increased automation
- Evaluate use of leasing of major hardware systems over a 3- to 4-year period to reduce the need for capital investment in hardware refreshment. The rapid progress in information technology requires that systems of this nature should be replaced every 3 to 4 years to maintain cost effectiveness.

The reengineering, hardware upgrades, software migration, and systems verification required to achieve these actions require a substantial investment. However, the investment can result in an 18 percent reduction the 10-year cost of the POIC.

- Invest approximately $6 million in FY 2002–2004 above the FY 2002 budget guidelines
- Reduce the operating budget in FY 2005–2011 to approximately $13 million per year (FY 2002 dollars)
- Achieve a reduction of $36 million (18 percent) from the FY 2002 budget over the 10-year period (FY 2002–2011).

4.2.5 POIC Recommendations

Recommendation 1. Develop a long-term plan for POIC evolution that provides for regular technology refreshment that will leverage technology progress, as well as anticipate future PI requirements.

Recommendation 2. Reengineer the POIC system in FY 2002–2004 to introduce current market technology and reduce operating cost, in accordance with the cost-reduction option described in Section 4.2.4.

4.3 Telescience Support Centers

In assessing the TSCs, the Study Team requested the Program Office to provide the following information on each TSC:

- A description (provided in the form of a user's guide for each TSC)
- Answers to several specific questions:
  - What are the functions and capabilities of the TSC?

- What payloads are supported by the TSC?
- What capabilities and functions does the TSC provide that are not provided by the POIC/POIF?
- What capability does the TSC have to process payload timeline planning, data, and commands independent of the POIC?
- What augmentation would be required to the TSC for it to conduct science operations without the POIC/POIF?
- What are the recurring operations costs for the TSC?

The responses to these questions were given in presentations by each TSC at the second meeting of the Study Team.

The assessments in this section are based on the material provided.

4.3.1 Description of Current TSCs

Currently, the four TSCs are located at ARC, GRC, JSC, and MSFC. The TSCs are generally multipurpose facilities that perform multiple services, payload operations representing only one area of services.

All of the TSCs provide host facility and information technology services for PI teams in a locale; these services typically include operational voice communications, local video processing and distribution, and data communications.

The ARC, GRC, and JSC TSCs also importantly provide facility class payload integration and timeline planning. Facility class payloads are generally ISS racks that contain equipment custom-designed to support the unique need of a single discipline, and within which multiple experiments can be operated. Current examples are the Biological Research Project (BRP) at ARC, the Fluids Integrated Rack (FIR) and Combustion Integrated Rack (CIR) at GRC, and the Human Research Facility (HRF) at JSC. Each TSC is responsible for the pre-increment integration and planning for research to be conducted in their facility rack, and on-orbit integration of payload operation as well as real-time control of the facility rack itself.

The MSFC TSC offers similar services for EXPRESS rack payloads but has delegated the responsibility for real-time control of the EXPRESS racks to the POIF.

All TSCs host and obtain synergy from related Research Project Office functions, such as scientific data archiving and flight facility and/or experiment development laboratories.

From the viewpoint of the payload operations architecture, TSCs can be regarded in function and capability as super-RPI sites. They are intended to perform functions similar to any RPI site, but for multiple payloads, or for a dedicated research facility-class rack.

Some characteristics of the individual TSCs are discussed below.

4.3.1.1 ARC TSC

Specialized functions:

- Facility class payload integration and timeline planning

- Monitoring and control of control group for biology experiments
- Science data processing
- Biology data archiving
- Hardware acceptance test and bio-compatibility testing
- Ten Mb/sec interface to Biology Research Project hardware at integration sites, launch sites, and onboard ISS
- Custom communications and data system for BRP data

Experiments currently supported:

- ADF (8A/UF-1/UF-2)
- BPS (8A/UF-1/UF-2)

Dependency on POIC:

- Voice and raw telemetry delivery
- Payload Planning System access

Resources:

- Operating budget: $1.1M/year
- Maintenance and sustaining engineering manpower: 3.5 FTEs
- Mission-dependent manpower: 3 FTEs + 7 EP/4 months

4.3.1.2 GRC TSC

Specialized functions:

- Facility class payload integration and timeline planning
- Science data processing and temporary storage

Experiments currently supported:

- SAMS
- FIR – late 2005
- CIR – no earlier than late 2005. Development uncertainties.

Dependency on POIC:

- Voice and processed telemetry delivery
- Trek workstations for command and control processing
- Payload Planning System access

Resources:

- Budget: \$1.2M/year
- Nine FTEs for facility engineering, maintenance, training, and operations

4.3.1.3 JSC TSC

Specialized functions:

- Facility class payload integration and timeline planning
- Data transfer to life sciences data archive
- Shared for MCC software testing, ISS simulations, and flight controller training

Experiments currently supported:

- Human Research Facility (HRF)
- Biotechnology (BSTC and BTR)
- ARIS-ICE
- Earth Observations
- EARTHKAM

Dependency on POIC:

- Voice and raw telemetry delivery
- Payload Planning System access

Resources:

- Budget: \$2.4M/year (\$0.2M/yr in ISS utilization budget; remainder RPO)
- TSC operations: 6.6 FTE
- TSC Data Systems: 12.9 FTE

4.3.1.4 MSFC TSC

Specialized functions:

- Hardware development and test

Experiments currently supported:

- Material Science and Biotechnology Glovebox experiments
- Protein Crystal Growth (PCG)

Dependency on POIC:

- Voice and processes telemetry delivery
- Trek

- Payload Planning System access

Resources:

- Budget: $0.36 M/yr
- 2.5 FTEs

4.3.2 TSC Findings

The Study Team evaluated the TSCs only against their ISS operations and utilization budgets. The POCAAS scope does not include other RPO-funded functions.

The Study Team observed that the ARC and GRC TSCs were principally designed for operation of dedicated facility racks. However, at ARC, the flight of space biology payloads will be limited by three-person crew time. At GRC, the FIR and CIR are planned no earlier than late 2005. Furthermore, the current mission model supports only one payload insert per dedicated facility rack per increment, as compared to the original plan for multiple inserts per increment. The payloads currently supported by the ARC and GRC TSCs require only RPI level support, which is typically provided at lower cost than the ARC and GRC budgets.

The JSC TSC is currently supporting HRF, other payloads, and other RPO functions, and is largely funded from other RPO sources.

The MSFC TSC is currently supporting EXPRESS rack payloads and MSG at a nominal cost.

Recommendation 1. Defer development and operating costs for the ARC and GRC TSCs until needed for dedicated facility rack operation, no earlier than 2005.

Recommendation 2. Transfer TSC responsibility from payload operations budget to RPO budgets. Do not consider TSCs as common-use payload operations services, but treat them as any other RPI site, with cost justified as part of the cost of payloads.

4.4 NASA Integrated Services Network

The current NISN budget will be discussed first, followed by a discussion of the Enhanced Communications for Payloads budget line item in FY 2004–2006.

4.4.1 NISN Budget and Services

The current NISN budget of $4.1 million in FY02 can be decomposed as shown in Exhibit 4-15.

The SSCC-POIC services and the POIC-TSC services consist primarily of T1 channels provided through the NISN network.

The POIC-WSC 50 Mb/sec data circuit is a satellite link that carries the KuBand data to both the POIC (for payload data distribution) and to the SSCC (for onboard video processing and recorded core system data). The cost of the satellite link is shared, and only the payload's 50 percent cost is shown here. This satellite service is under a contract which expires in 2 years.

The A/G video to the ARC and GRC TSCs is via a leased satellite channel, while the A/G video distribution to the RPIs is planned via mpeg over the Internet. The cost is for Internet 2 access

Exhibit 4-15. FY 2002 NISN Budget

Services	Budget ($k)
SSCC-POIC – voice, S-Band data, A/G video	935
POIC-WSC – voice and 50 Mb/sec KuBand data	1051
POIC-TSCs – voice and data	571
A/G Video to ARC and GRC TSCs	240
A/G Video to RPIs	540
IVoDS (begins March 2002)	205
HVoDS to 10 RPIs (temporary until IVoDS)	196
Data to RPIs via Internet	250
Miscellaneous	120
Total	**4108**

services. The A/G video is currently converted to mpeg format at the SSCC, and transmitted to the POIC as part of the SSCC-POIC data stream.

Voice distribution to the RPIs is currently provided via HVoDS instruments, which operate over leased circuits to the POIC voice system. RPI operational voice requirements include the ability to monitor as many as eight different voice loops simultaneously, while talking on one. The IVoDS development enables voice transmission over the Internet, using voice-over-IP (VOIP) technology, and using PC software at the RPI to control the voice loops.

The FY 2002 budget level is essentially continued through FY 2006, with 10 percent increases each year.

4.4.1.1 NISN Budget Findings

The priority of delivering onboard video to all TSCs and RPIs for operation of payloads is unclear. Some payloads requiring video for operation have embedded payload-unique video into their KuBand data streams. Although general distribution of video is good public relations, its value should be balanced against cost. If only a few payloads require onboard video for payload operation, not all at the same time, less expensive alternatives may exist. Potential alternatives include call-up satellite transmission service, as used by local television stations, or use of NASA TV for limited periods. NASA TV was used throughout the Spacelab Program for general dissemination of onboard video transmissions.

HVoDS can satisfy RPI requirements (10 sites) through 2003 for equal or less cost than IVoDS. Longer term cost savings with IVoDS, as RPI requirements increase, are dependent upon resolution of technical issues, primarily the bandwidth requirements for satisfactory operations (up to 300 Kb/sec per remote instrument). Another factor is the anticipated technology refreshment of the HVoDS system in the 2005 time frame, and what capabilities a replacement system may offer for remote voice distribution. VOIP technology is developing very rapidly, and commercial products may become available at lower cost.

The cost for the POIC-WSC circuit is locked in by contract through 2003; however, the current marketplace offers equivalent service for less cost. A 50 percent or greater cost reduction is possible in 2004.

Similarly, the NISN costs for the T1 channels used for transmission of voice and data between the SSCC and POIC, and POIC and TSCs, are a multiple of current commercial T1 costs.

Observation. NISN budget projects increases of 10 percent per year over the next 3 years, while commercial data communications costs are dropping by 40 percent per year.

4.4.1.2 NISN Recommendations

Recommendation. Pursue alternative means of providing needed communications services at lower cost.

Recommendation and Cost Option 1. Defer the requirement for general video distribution to the TSCs and RPIs, with a cost reduction of $780K/year. Address specific payload operations requirements on a case-by-case basis, and budget as an optional service to the payload. Reevaluate the use of NASA-TV for limited payload requirements.

Recommendation and Cost Option 2. Reevaluate implementation of IVoDS, and consider deferral of implementation until payload requirements and technical status justify the move from HVoDS. The reevaluation should include commercial alternatives to the current custom solution.

4.4.2 Enhanced Communications for Payloads

The FY 2004–2006 budgets contain $24.9 million for enhanced communications for payloads. The origin of this item is a projected requirement for 150Mb/sec data downlink via the KuBand system, an upgrade from the 50Mb/sec capability currently provided.

4.4.2.1 Background

The ISS KuBand communications subsystem was designed to provide 150Mb/sec service on the return link for payload data. The ground network, however, can currently support only 50 Mb/sec. This includes the circuits from WSC to MSFC and JSC, and the front-end processors at MSFC and JSC. The plan was that, when user bandwidth requirements exceeded the current 50Mb/sec capability, the ground network could be upgraded to accommodate the higher rate already available from the vehicle.

A plan for implementing this upgrade was built into the CSOC contract in the form of the so-called "Option 6". This contract option is intended to provide 150Mb/sec circuits from WSC to MSFC and JSC as well as provide for the development of new front-end processors to handle the higher rate from the ISS. However, no provisions exist for any upgrades to the on-board data system in CSOC Option 6. The current estimate for exercising Option 6 is in the neighborhood of $34 million.

In 2000, NASA entered into an agreement with Dreamtime, Inc., to provide a significant amount of high-definition television (HDTV) from the ISS. This project immediately drove the bandwidth requirements above the 50Mb/sec level. CSOC was asked to investigate ways to implement HDTV on the ISS KuBand return link.

Dave Beering (now the CSOC chief engineer) developed a concept that would replace the end-to-end KuBand system (space and ground segments) with commercial data communications technology. This concept, called “Enhanced Option 6”, is based on the asynchronous transfer mode (ATM) link layer and would provide transparent connectivity between the on-board systems and the ground network at the standard ATM rate of 155Mb/sec. Enhanced Option 6 is estimated to cost about $28 million.

The original Option 6 has the disadvantage of requiring the investment of a sizeable amount of money in developing new 1980’s technology hardware. The commercial telecommunications industry has evolved very rapidly over the past 20 years and now has many solutions that far exceed the requirements of the ISS. Many advantages exists to upgrading to commercial telecommunications technology both in terms of cost and of performance:

- Some components of the current KuBand space segment, such as the high-rate frame mux (HRFM) and video baseband signal processor (VBSP), have only one spare. Loss of either of these components will create single points of failure that will be difficult to recover from should another failure occur. The upgrade to commercial technology will eliminate the need for these components.
- Technology upgrade paths are continuously being developed and are available from multiple vendors.
- Maintenance and operation of commercial equipment is less expensive
- Software products are commercially available to provide services over commercial network interfaces.
- Network security solutions are readily available and need not be custom developed

4.4.2.2 Findings

The Study Team was unable to identify any driving requirement in the near term greater than the 50 Mb/sec data rate. However, as the number and variety of payloads increase, additional requirements will likely arise.

Several options are available to increase the current 50 Mb/sec bandwidth, recognizing that the ISS onboard system can currently support 150Mb/sec, but that the ground systems cannot:

- **Option 1.** Use the existing WSC-POIC/PDSS architecture, and increase the WSC-POIC circuit bandwidth to 75 Mb/sec. The approximate circuit cost, if implemented after 2003 when the current circuit commitment expires, would be less than $750K, which is less than the current 50Mb/sec circuit cost. (This option does not consider circuit cost to the SSCC associated with this upgrade.)
- **Option 2.** Use the existing WSC-POIC/PDSS architecture, but implement the POIC FY 2002 initiative (see Section 4.2.4) to reduce PDSS operating cost. This initiative also will increase the PDSS capacity to allow 150Mb/sec service. Increase the WSC-POIC circuit bandwidth to 150Mb/sec. The approximate circuit cost (after 2003, as for Option 1) would be approximately $1.5M/year.
- **Option 3.** Implement a variant of CSOC Enhanced Option 6, which would enable industry-standard data communications from an ISS payload direct to an RPI via the

Internet (see Section 5.1, Option F, for further discussion). This option shifts the PDSS function to WSC and could significantly increase the ability of PIs to communicate transparently with their payloads. The approximate development cost is approximately $25 million; annual operating cost would be similar to the other options.

The upgrade to 150 Mbs should be accomplished when the requirements mandate the additional bandwidth. When the requirement does exist and in consideration of obsolete systems that need replacement, it would be the appropriate time to implement the CSOC Enhanced Option 6 that would replace and upgrade technology both on ISS and in the ground system.

4.4.2.3 Recommendations

Recommendation and Cost Option 1. Defer the requirement for an increase in the current 50Mb/sec capability until a justified payload requirement, or requirement to replace the onboard ISS system, is defined. When a requirement is defined, evaluate the alternative ISS onboard and ground implementation alternatives to meet the requirement.

Recommendation 2. In the longer term, the Study Team recommends migration to the use of industry-standard data communications directly from an ISS payload to an RPI via the Internet. This option could significantly increase the ability of PIs to communicate transparently with their payloads.

4.5 Cost Reduction Options Summary

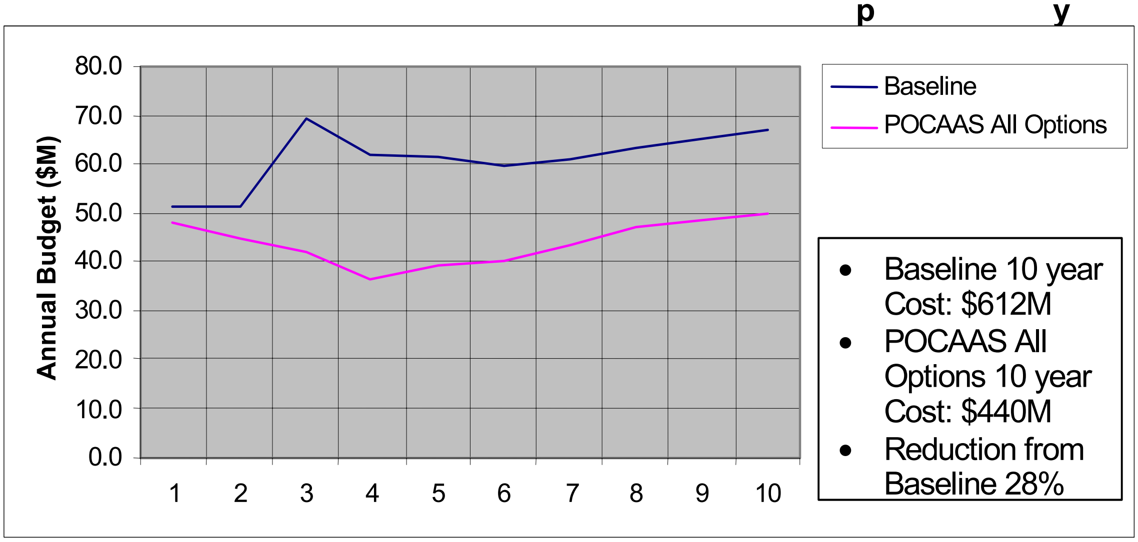
A comparison of the current payload operations budget incorporating all cost options recommended by the Study Team is shown in Exhibit 4-16. The current budgets provided to the Team have been projected beyond 2006 using a 3-percent escalation factor. The same escalation factor has been applied in constructing the POCAAS minimum service cost. For POIF, a labor cost of $125,000 per person-year has been assumed, derived from the FY 2002 budget of $22 million and contractor LOE of 175.

Exhibit 4-16. FY 2002 vs. Minimum Service Cost

UPN		ITEM	02	03	04	05	06	07	08	09	10	11	01-11
FROM 39X RESEARCH PROGRAMS													
		TSCs	3.2	2.7	2.6	3.5	2.7	2.8	2.9	3.0	3.1	3.2	29.7
		POCAAS	0	0	0	0	0	0	0	0	0	0	0
FROM 479 PAYLOAD OPERATIONS AND INTEGRATION													
479-20	JSC	NISN (SOMO)	4.1	4.5	5.0	5.5	5.7	5.9	6.0	6.2	6.4	6.6	55.9
		POCAAS	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	34.5
479-41	JSC	ENHANCED COM			16.0	5.3	3.6						24.9
		POCAAS	0	0	0	0	0	0	0	0	0	0	0
479-42	JSC	P/L TRNG-TSC (PTC)	1.0	0.4	0.4	0.3							2.1
		POCAAS	1.0	0.4	0.4	0.3							2.1
479-42	JSC	P/L TRNG-SFOC (PTC)	1.1	1.9	1.9	2.1	2.3	2.4	2.5	2.6	2.7	2.8	22.3
		POCAAS	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	3.4
478-43	JSC	PPS	0.3										0.3
		POCAAS	0.3										0.3
479-22	MSF	POIF (+65 CS)	22.0	23.9	25.1	26.0	26.9	27.7	28.5	29.4	30.3	31.2	271.0
		POCAAS (+50 CS)	22.0	20.9	17.1	18.5	20.8	21.4	24.2	27.2	28.0	28.9	229.1
479-XX	MSF	POIC & PDSS	18.4	17.1	17.8	18.2	19.1	19.7	20.3	20.9	21.5	22.1	195.0
		POCAAS	20.4	19.1	19.8	13.0	13.4	13.8	14.2	14.6	15.1	15.5	158.9
479-43	MSF	PPS	1.1	0.8	0.8	1.1	1.1	1.1	1.2	1.2	1.2	1.3	10.9
		POCAAS	1.1	1.0	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.3	11.3
		BASELINE TOTAL	51.2	51.3	69.6	62.0	61.4	59.6	61.4	63.3	65.2	67.2	612.2
		POCAAS	48.1	44.8	41.8	36.5	39.0	40.2	43.6	47.1	48.5	49.9	439.6

The total cost comparison is shown graphically in Exhibit 4-17.

Exhibit 4-17. Baseline Architecture Cost Option Summary



4.6 Organization and Contractor Findings

In the course of the POCAAS, the Study Team noted instances of a lack of common purpose and integrated approach to achieving enhanced research results and a more effective total organization.

Organization Recommendation. To achieve the efficiencies reflected in the POCAAS cost options, technical integration must be strengthened both among the payload operations elements (POIF, POIC, and NISN), and between the payload operations and engineering integration elements of the program.

The Study Team also recognizes that the POIC is planned to transition from the UMS contract to the CSOC contract at the end of FY 2003. However, the reengineering of the POIC to reduce cost will require several years to complete, and a transition during the reengineering process could result in schedule delay and increased cost. The POIF contract (NASA 50000) expires near the end of 2005, coinciding with scheduled commencement of IP payload operations.

Contract Recommendation. NASA should evaluate the phasing of contract transitions in view of ISS phasing and cost-reduction goals.

5. Alternative Architectures and Mission Concepts

The Study Team evaluated six alternative payload operations architectures and six alternative mission concepts.

5.1 Evaluation of Alternative Payload Operations Architectures

The Study Team defined *architecture* to mean a distribution of functions among payload operations elements. The elements in the architecture were those described in Section 3.3 (SSCC, PCCs, POIF, POIC, TSCs, NISN). The Study Team found no reason to define additional architectural elements. The Team considered that the basic functions of the POIF, and POIC must be provided in some way within a valid architecture.

In addition to the alternate architectures presented here, the Study Team discussed variants to this set, but found none that were practical, distinctly different, or offered significant advantages over those presented.

5.1.1 Definition of Alternative Payload Operations Architectures

The Team evaluated six alternative architectures:

- Current architecture
- Reengineered current architecture (see Section 4)
- Rotate POIF functions among the POIC and IP PCCs
- Rotate POIF and POIC functions among the TSCs
- Move POIF/POIC to SSCC
- Space Internet infrastructure

The Study Team evaluated the alternative architectures to determine their relative effect on ISS research utilization, the 10-year cost of payload operations, and other significant factors. Ten-year cost was used rather than annual recurring cost to account for investments required in some alternatives.

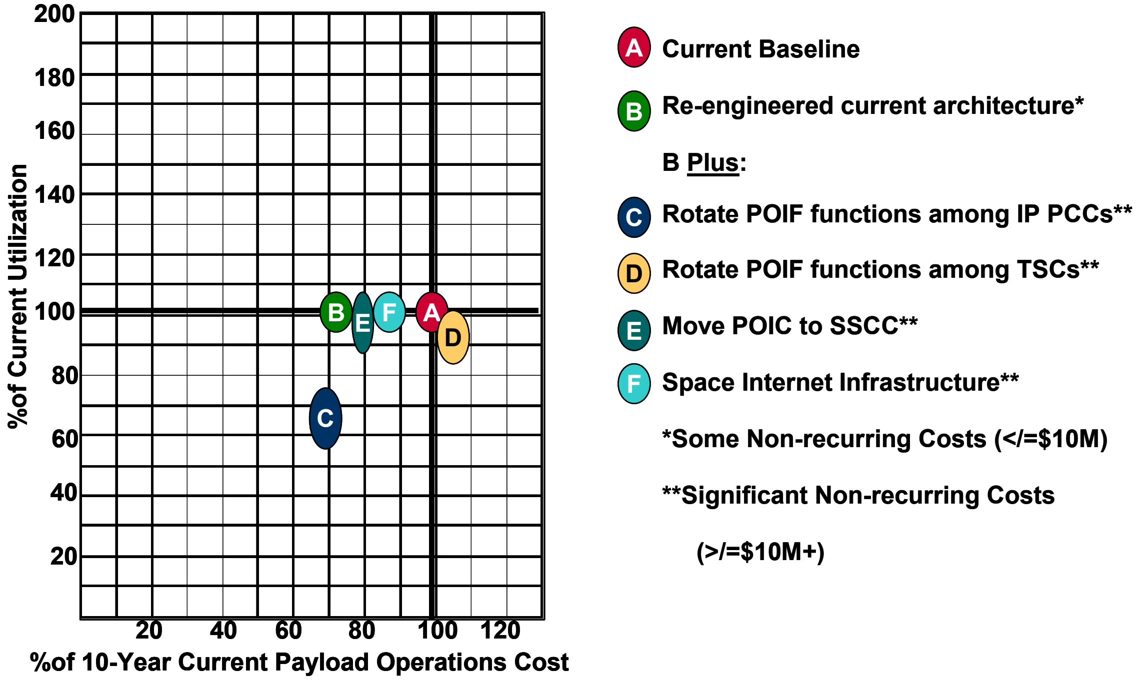
In evaluating the recurring cost, the Team assumed that all architectures except Alternative A (the current architecture) adopted the efficiencies projected in the minimum service level principles used in Alternative B (the reengineered current architecture).

The relative comparison of each alternative against research utilization and recurring cost is shown graphically in Exhibit 5-1, with a qualitative statement as to the significance of other advantages and disadvantages. Each alternate architecture is then discussed in turn.

A. Current Architecture

The current architecture is described in Section 3.3. In Exhibit 5-1, it represents the origin of the coordinate system against which the other architectures are compared.

Exhibit 5-1. Notional Research/Cost Evaluation of Alternative Architectures



B. Reengineered Current Architecture

This architecture incorporates the reengineering of requirements, processes, and functions as discussed in Sections 2.4.5 and 4.1.3.1. The reengineered architecture has lower cost than the current architecture (Alternative A) and provides an improved environment for research. This alternative has no disadvantages to Alternative A.

C. Rotate POIF Functions Among the POIC and IP PCCs

In this architecture, the ESA PCC, NASDA PCC, and the POIF/POIC would each assume control of ISS payload operations for one shift per day.

The IP PCCs would be required to develop the capability to use the U.S. C&DH, and to develop capability to operate the U.S. PLSS. Each PCC would be required to operate the Payload Planning System, to acquire and train staff to integrate all U.S. and IP payload operations, and to interface with U.S. remote PIs, TSCs, and the SSCC. It was assumed that the U.S. POIF would continue to perform the crew support functions of display review, procedure integration, and training coordination. However, the IP PCCs would have to become familiar with crew procedures for U.S. payloads to provide real-time support, and to be able to provide the ground-to-air payload communications interface during on-orbit operations, and to manage and implement on-orbit PODF changes.

The SSCC would be required to interface with multiple PCCs. Shift handovers would require not only a payload handover from the previous shift PCC, but also an SSCC handover between PCCs.

Each PCC would incur one-time cost for modification of its IT infrastructure to operate with the U.S. C&DH, and to acquire and train staff for the POIF functions. Each PCC would incur recurring cost for POIF staff and the modified IT infrastructure.

It was assumed that the U.S. would not provide monetary compensation to the IPs for their increased cost but, rather, would barter payload resources as compensation. (The U.S. is obligated under the terms of the international MOUs to provide the POIF.) It was estimated that the amount of compensation would be in the range of 25 to 45 percent of the U.S. payload resources.

U.S. POIF costs would be reduced by two shifts of real-time support, or about 20 percent of total POIF labor. This reduction in POIF labor amounts to a 7-percent reduction in U.S. payload operations cost. However, this cost reduction would be offset by (1) increased SSCC labor, due to the multiple interfaces created, (2) one-time cost to the U.S. POIF to transfer knowledge and procedures to the IP PCCs, and (3) recurring cost to the U.S. POIF for continuing transfer of information on U.S. payloads to the IP PCCs.

The rotation of responsibility for safety assurance of payload operations would increase the scope of safety-critical operator certifications required, and potentially increase safety risk due to the additional interfaces and divided responsibility.

The net effect of this architecture would be a more complex operation with increased interfaces, an uncertain but possible small reduction in U.S. payload operations cost, and a large reduction in U.S. research resources. This option was judged by the Study Team to be unacceptable.

D. Rotate POIF/POIC Functions Among the TSCs

In this architecture, each TSC would in turn provide the POIF function for an increment. Each increment would be operated in a campaign mode, where the discipline focus of the responsible TSC would be given priority in research conduct. (The campaign mode itself is evaluated in Section 5.2 as an alternate mission concept.)

Each TSC would be required to develop the information infrastructure to provide POIC-like capabilities, with associated communications. The PDSS was assumed not to be duplicated. However, each TSC would require the control rooms to accommodate POIF staff, full capability for command and telemetry processing, and full capability for the POIF tools (such as PPS). Each TSC would be required to interface with the SSCC information systems, and the SSCC would be required to interface with four TSCs rather than one POIC. The one-time cost to duplicate POIC is conservatively estimated at $20 million. This assumes transfering the POIC system design without modification and sustaining engineering provided by the staff at the current POIC.

POIC operating cost would be reduced by limited operation 75 percent of the time. This savings would be offset by increased IT operating staff at the TSCs.

Each TSC would develop duplicate capability to control the U.S. PLSS, to operate EXPRESS racks, to interface with other TSCs, to interface with the SSCC, and to interface with IP PCCs. Each TSC would be responsible for full pre-increment planning and preparation, including crew support. The added labor for four TSCs is estimated at four times 50 percent of reengineered POIF labor, while the one times 100 percent of re-engineered POIF cost would be saved.

RPIs would be assigned to a TSC for support, but because not all TSCs would support every increment, RPIs would potentially have to interface with multiple TSCs or not be able to operate during certain increments.

SSCC and IP PCC operating cost would be increased by an increased number of interfaces.

The Team estimated that a 10-percent reduction in ISS resource utilization would result due to the increased complexity of operations and limitations on manifesting likely to result from this architecture. It would be very difficult to maintain consistent and effective interfaces among the multiple architectural elements involved.

The rotated responsibility for safety assurance of payload operations would increase the scope of safety-critical operator certifications required, and potentially result in increased safety risk due to the divided safety responsibility.

The net effect of this architecture was judged by the Study Team to be a much more complex operation with increased cost. Research resource efficiency would probably be reduced. The Team judged this architecture to be unacceptable.

E. Move the POIF/POIC to the SSCC

In this architecture, the SSCC would be augmented to provide the POIF and POIC functions, including support to the TSCs and RPIs.

The assessment of this option was performed based on a briefing to the Study Team provided through the ISS Program Office, which identified the functional differences between SSCC information systems and POIC information systems. However, JSC declined to present an assessment of potential impacts associated with this option. Therefore, the analysis presented is that of the Study Team.

The Study Team considered two options for SSCC augmentation to provide POIC payload data services.

In Option 1, the existing POIC information systems would be moved to empty space in the SSCC. Assuming that facilities were available, 1 to 2 years of POIC downtime would be required for the move, resulting in an equivalent ISS stand-down from payload operations. During the course of the move, POIC cost would continue until an equivalent staff was reconstituted at JSC. Because it is unlikely that the current POIC staff would transfer intact, increased cost would be expected during this period for overlap and training of the new staff. The POIC recurring cost would not be reduced.

In Option 2, the existing SSCC information systems would be modified to provide POIC functionality. While this option would offer the greatest synergism, the magnitude of the reengineering effort was estimated at $20 million. The SSCC effort would require 1 to 2 years, and would require care to avoid impact to ongoing SSCC operations. After the SSCC began payload operations, the POIC recurring cost would be eliminated, but an increase in SSCC recurring cost would occur due to the added functionality and TSC/RPI interfaces.

The POIC was assumed to continue operating while the SSCC is being reengineered, so that payload operations would continue.

In addition to the POIC, the POIF staff would be reconstituted at the SSCC. Because it is unlikely that the current POIF staff would transfer intact, 1 to 2 years would be required to recruit and train POIF staff at the SSCC. Assuming that payload operations were continued during this period at the POIC, additional POIF cost equal to 1 to 1.5 years would be incurred, or $14 million to $21 million.

During the changeover between the POIC and SSCC, some limited stand-down time might be expected. (A separate analysis of the merits of a stand-down from all ISS payload operations is discussed in Section 5.2 as an alternate mission concept). The stand-down time would result in a loss of ISS research resources.

The potential synergistic advantage gained through integration of payload operations into the SSCC are undefined and argumentative, given the differing responsibilities and criteria of the SSCC for safe core systems operations and the POIC for facilitating research. The SSCC responsibilities require tight control and minimum risk, while the POIC responsibilities require flexibility while payload mission risk is traded against research innovation and cost. In the Spacelab Program, these factors led to relocation of the Payload Operations Control Center from the MCC to MSFC.

Currently, crew training is performed at the SSTF at JSC by both POIF personnel and SFOC instructors. It is advantageous for crew accessibility to conduct payload crew training at the SSTF. However, two sets of instructors are not necessary. Cost Options 1 and 2 recommend using MSFC POIF instructors co-located at JSC and eliminating SFOC payload training instructors.

A further negative factor in this architecture is the resultant loss of the institutional knowledge and skill base in manned payload operations that currently resides at MSFC. This base represents the experience of 20 years of operation during the Spacelab, Shuttle, and ISS programs, and a recognized leadership in payload advocacy.

The Study Team judged the known impact of this architecture to be a 1- to 2-year period of increased cost (approximately $40 million to $80 million), no significant reduction in operating cost, a potential loss of research resources utilization, and no clear advantages. The Study Team does not recommend this architecture.

F. Space Internet Infrastructure

This architecture assumes the extension of commercial communications standards, compatible with the Internet, into the ISS onboard and ground communications systems.

A logical evolution of space communications includes the use of commercial standards and equipment in space. Exhibit 5-2 illustrates the resulting architecture, which has been successfully demonstrated in a pilot freeflyer program.

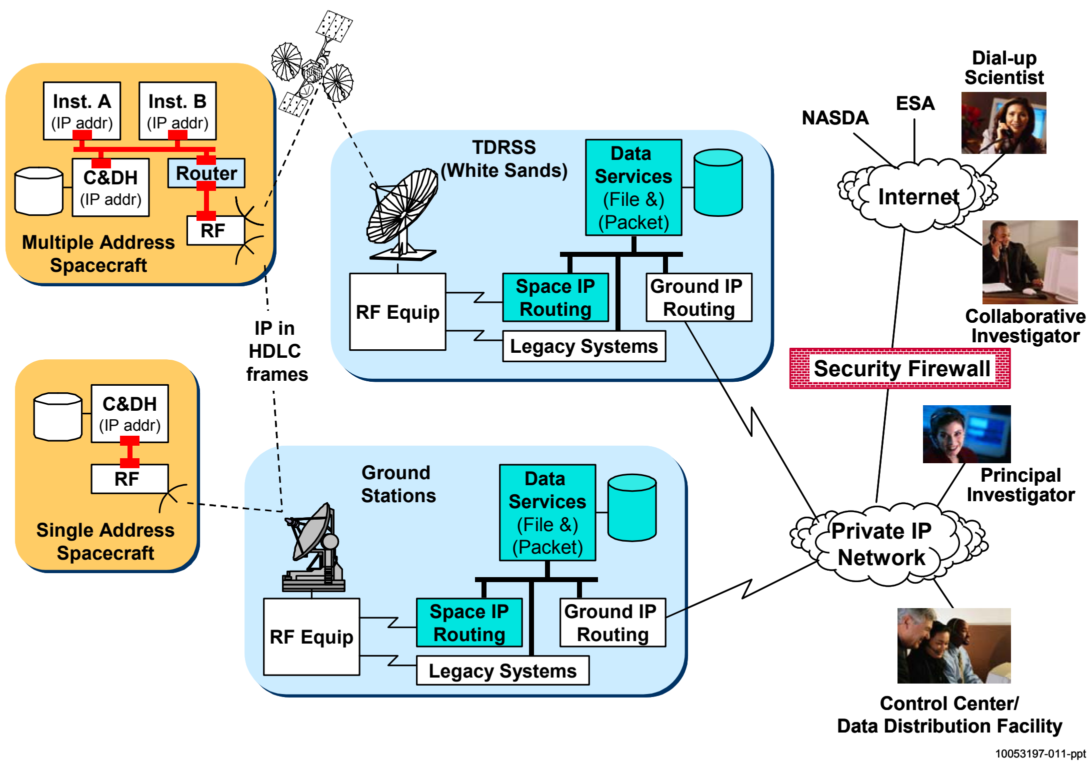
This architecture has been previously proposed for the ISS Program as "CSOC Enhanced Option 6." It offers the advantages of using commercial technology rather than custom hardware and protocols. It would enable researchers to communicate directly with their space experiments across the Internet. Its application could in the long-term significantly enhance research capabilities, reduce the payload operations infrastructure, and reduce recurring costs.

However, this architecture requires a significant modification to onboard ISS systems, space-hardening of commercial ground communications products, and modifications to the ground communications and data processing systems. Use of direct uplink capability also introduces security issues. While these issues can be mitigated with current technology, resolution of the issues require policy decisions as well as technical consensus.

The ideal time to implement a new onboard architecture is when requirements increase which require onboard system modification, or when obsolete or failed systems onboard the ISS have to be replaced for those reasons.

The Study Team believes this architecture represents a desirable evolution in space communications and, therefore, merits long-term consideration in the ISS Program.

Exhibit 5-2. Space Internet Architecture



5.1.2 Alternate Architecture Summary

The information systems of the POIC are the enabling resource for telescience. The POIC was specifically designed to support payload telescience requirements.

The POIC represents a major program investment in time and dollars. The POIC capabilities are not easily duplicated or moved.

Most POIF functions are more cost-effectively centralized rather than duplicated in multiple locations. Duplication of personnel and skills in multiple locations results and increased cost and increased complexity of interfaces. The only existing capability is at the POIC.

Centralization of the POIF function of ensuring the safety of payload operations improves consistency and reliability in this critical area.

Each current TSC is dependent upon POIC information system services.

Each TSC currently provides capability equivalent to a super-RPI site but not equivalent to the POIF or POIC. Each current TSC does not have the resources or skills to perform POIF integration functions.

Alternate Architecture Recommendation. The best path to cost reduction is through reengineering and continuous improvement of the current architecture and processes.

5.2 Alternate Mission Concepts

The Study Team defined a mission concept as a principal way of operating the ISS to accomplish its goal of enabling world-class research.

In addition to the alternate concepts presented here, the Study Team discussed other concepts and variants on the concepts presented. No other concept was found that was practical, distinctly different, or offered significant advantages over those presented here.

5.2.1 Definition of Alternate Mission Concepts

The Study Team evaluated six alternate mission concepts

A. Current Baseline

B. Reengineered Current Baseline

G. Campaign Mode

H. No Increment Planning Overlap

I. Added crew Time — EDO/Soyuz

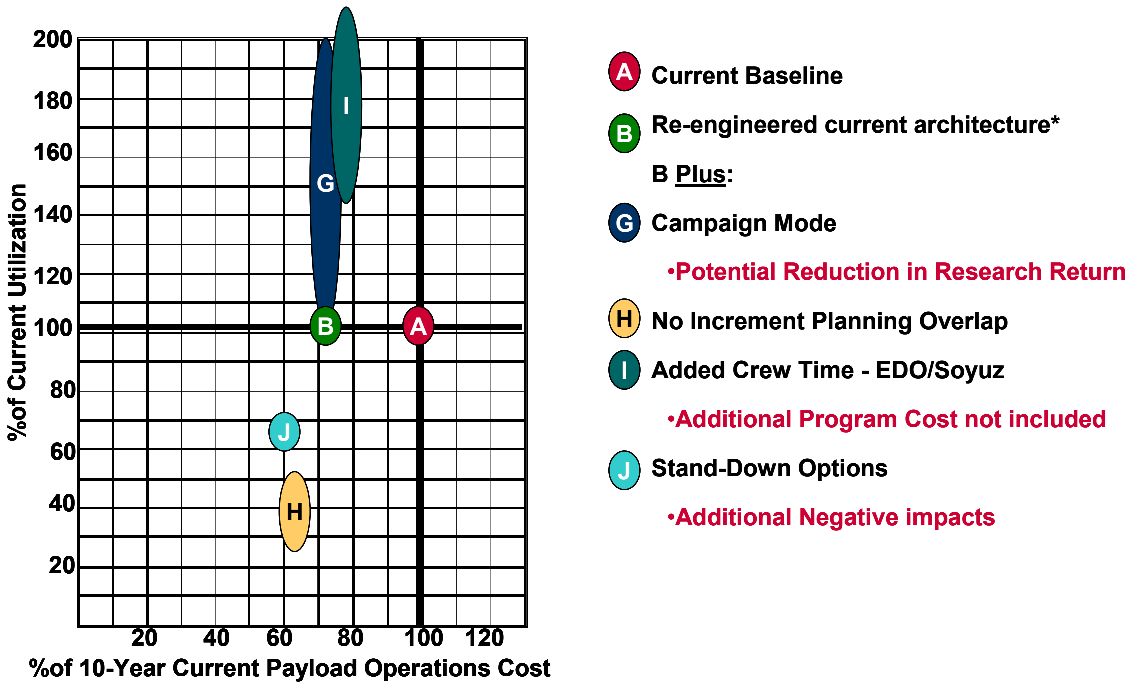
J. Stand-down Options

The Study Team evaluated the alternative mission concepts to determine their relative effect on ISS research utilization, the 10-year cost of payload operations, and other significant factors. Ten-year cost was used rather than annual recurring cost to account for investments required in some alternatives.

In evaluating the recurring cost, the Team assumed that all mission concepts except Concept A (the current architecture) adopted the efficiencies projected in the minimum service level principles used in Concept B (the reengineered current architecture).

The relative comparison of each alternative concept against utilization and recurring cost is show graphically in Exhibit 5-3, with a qualitative statement as to the significance of other advantages and disadvantages. Each alternate concept is then discussed in turn.

Exhibit 5-3. Notional Research/Cost Evaluation of Alternative Mission Concepts



A. The current architecture

The current architecture is described in Section 3.3. In Exhibit 5-1, it represents the origin of the coordinate system against which the other architectures are compared.

B. Reengineered Current Architecture

This architecture incorporates the Minimum Service Level Model described in Section 4.1.3. The reengineered architecture has lower cost than the current architecture (Concept A), but does not imply any change in ISS manifesting or research utilization. This alternative has no other significant advantages or disadvantages over Concept A.

G. Campaign Mode

The campaign mode assumes each increment research discipline area (life sciences, microgravity sciences, and space products) is sequentially assigned an increment in which it is allocated all of the available resources it requires.

The ISS Payloads Office analyzed this mode for the three-person crew mission phase using their payload utilization modeler (PLUM). The research resource requirements were provided by the RPOs. The human research discipline was assigned 80 percent of its required crew time, which is all that is available with a three-person crew. Other disciplines were selected randomly to use any resources remaining after the primary discipline was scheduled. The analysis results are shown in Exhibit 5-4.

Exhibit 5-4. Campaign Mode Analysis

Discipline Resources Achieved (% of Discipline Requirement)

Discipline	Allocated Discipline Campaigns, Augmented*				No Campaign (Random)	Efficiency Ratio**
	Life Sciences	Micro-gravity	Space Product	Avg		
Life Sciences	52.5	2.9	4.1	19.8	12.3	1.61
Micro-gravity	4.5	38.9	4.7	16.0	15.7	1.02
Space Product	2.8	6.6	100.0	36.5	16.5	2.21
Average				24.1	14.8	1.63

Life Sciences:	**Human Research Fundamental Biology - Cell Culture Research**
Microgravity:	**Materials Science Fluids & Combustion BioTechnology**

Assumptions

- U.S. Racks Only
- Pre-CAM
- 3 Crew
- Reduced HRF capabilities (80%)
- U.S. Crew time: 13.5 hrs/wk
- Crew Training: 473.4 hrs
- Upmass: 3467 kg
- Middecks: 10 MDLs
- Power: 32.43 kW
- Keep-Alive Power: 14.21 kW

* **Equal campaign opportunities provided to Life Sciences, Microgravity, and Space Product Development (SPD) according to the 30-30-30-10 allocation. Non-prime discipline research augments each campaign where resources allow.**

** **Average Discipline Campaign ÷ No Campaign**

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Exhibit 5-4 illustrates that the use of campaign mode increases achievement of discipline resource objectives, averaged over multiple increments. However, campaign mode results in very low resources for disciplines that are not prime during an increment. The no campaign mode provides a lower but continuous level of resources to all disciplines.

The effect on research productivity depends upon the value of continuity in access to space (no campaign mode) versus the value of increased resource availability (campaign mode). Commercial users need timely, frequent, and repeated access to the ISS, while other disciplines may favor other strategies.

A partial campaign mode that provides an emphasis to one discipline at a level less than their full requirement may offer the best compromise, given the present research priorities.

The use of campaign mode was judged to have no effect on payload operations costs.

H. No Increment Planning Overlap

This mission concept assumes that a reduced POIF staff plans, prepares, and then executes one increment at a time (no overlapping planning activities).

With a 6-month planning and preparation cycle, this results in payload operations being conducted on one increment in three. Alternatively, six-month increments could be used, with payload operations being conducted on one increment in two. No payload operations are conducted on the intermediate increments, so that research resource utilization is between 33 percent and 50 percent.

POIF staff would be reduced by an estimated 30 to 50 percent due to reduced real-time and operations preparation workload. This reduction in staff would result in a total payload operations cost reduction of approximately 8 percent relative to mission Concept B.

I. Added Crew Time – EDO/Soyuz

This mission concept provides additional crew time for research by using the Shuttle EDO capability during ETOV visits.

A six-person crew is needed to achieve the full benefits of human conduct of research onboard the ISS. Some career scientist crew members are also required, either within the career astronaut corps or as payload specialists from the research community.

In the interim, until a continuous six-person crew can be supported, use of the EDO and extended Soyuz missions can increase the crew time available for research. This option was discussed in the ICE Report of the IMCE Task Force, and is further discussed in Appendix E.

Estimates of the increased research utilization vary depending upon assumptions as to the number of Shuttle flights, overlap times, and mid-deck locker space available. Differing options also exist for the use of the increased crew available during the overlaps. (The EDO crew could be used to perform ISS maintenance, freeing ISS crew time over the remaining increment for more research. Or the EDO crew could concentrate on research itself, in a campaign mode.) The range shown in Exhibit 5-4 represents this variation.

The Study Team assesses some increase in recurring payload operations costs due to increased crew training, timeline planning, and real-time coordination with this concept. The magnitude of the increase is dependent upon utilization option selected.

The full program cost effect of implementing EDO/Soyuz missions was not assessed in the POCAAS.

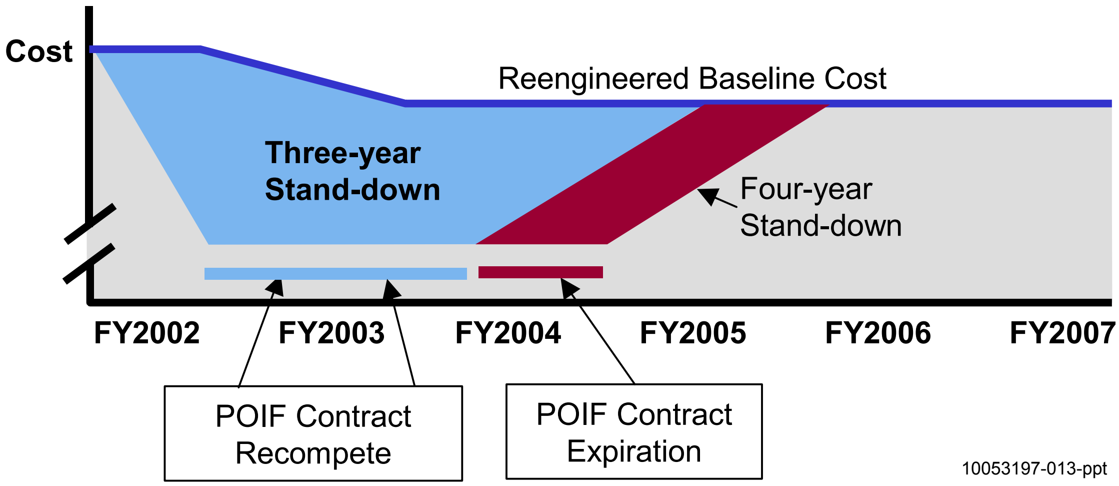
J. Stand-Down Option

This concept assumes a complete stand-down from payload operations for an extended period of 3 to 4 years, in order to reduce cost.

Cost savings from a stand-down results from reduction in POIF and POIC staff during the stand-down, as well as reduction in communications costs. The costs savings during a stand-down could be used to reengineer payload operations to reduce out-year recurring cost, payload development, or other research activities.

A notional stand-down time profile is shown in Exhibit 5-5.

Exhibit 5-5. Notional Stand-Down Time Profile



Payload operations staff would be reduced over the period of 1 year, as increments already in preparation and their PI commitments are completed. At the bottom of the stand-down, POIF staff would be reduced to a minimum level for retention of skills. POIC operations staff would be similarly reduced, but sustaining engineering and maintenance activities would necessarily be kept to maintain integrity of systems and software.

The return to operations after a full stand-down is estimated to require 2 years for rehiring and retraining POIF and POIC staff, system reverification, and increment preparation.

If return to operations requires 2 years, a stand-down of at least 3 years is required to achieve cost savings. The estimated savings is $27 million for a 3-year stand-down, and $44 million for a 4-year stand-down.

A stand-down of 3 to 4 years out of 10 results in a 30 to 40 percent loss of research resources and commercial opportunities.

A return to operations is required to take place before 2005 so as not to delay IP payload operations, which would impact the international MOUs.

A stand-down before September 2004 incurs termination costs for the POIF contract, and requires immediate recompete to have a vehicle in place to enable rehiring.

The Study Team believes that a stand-down would result in severe loss of researcher support for the ISS, as well as loss of NASA credibility. It would also result in loss of payload operations expertise and loss of U.S. stature. The Study Team strongly recommends against this concept.

5.2.2 Alternate Mission Concept Summary

Recommendation. Continue analysis of the campaign mode to determine optimum manifesting to maximize achievement of research objectives, including resource utilization.

Recommendation. Pursue increased crew time for research, including EDO/Soyuz options, as possible within funding constraints.

6. Recommended Changes to User Requirements

The Study Team analyzed interim and permanent changes to current NASA user development requirements that could reduce payload operations costs.

The Team did not identify any specific instances where current user practices are over-driving payload operations requirements and costs. However, users can reduce payload operations workload and cost in several ways.

- Defer the need for RPI access to ISS downlink television, where not essential to experiment operation. Where television access is required, seek the lowest cost and available implementation, and treat the service as an optional service with added cost for that experiment.
- Deliver quality operations products on schedule. Late deliveries and poor quality products cause workload peaks and rework of operations products.
- Minimize C&DH database changes after baselining. Late changes cause workload peaks and rework of operations products. Currently, there are three to four database deliveries per mission segment.
- Keep data requirements within the current 50 Mb/sec downlink capability.
- Use telescience to minimize crew support costs. However, total experiment cost may be reduced by the use of crew time.
- Design payloads to satisfy multiple investigations and to maximize hardware remaining on-orbit, while minimizing upmass, downmass, and installation activities.
- Take advantage of operations experience and lessons learned by considering operations requirements and performing operations strategic planning from the beginning of payload design and development. Establish an early dialog with POIF staff.

7. Recommendations on Changes to the ISS Concept of Operations that Take Full Advantage of the Continuous Operations Environment Afforded by the ISS

The primary characteristic of the ISS that sets it apart as a world-class research facility is the capability to provide a laboratory in space with continuous access to the microgravity environment and vacuum of low-Earth orbit. Within crew time and resource constraints, continuous payload operations offer unlimited laboratory time on orbit for support of research. Inherent in this continuous operations environment is the ability to conduct extended uninterrupted research activity on a specific experiment.

Equally significant to quality scientific research is the potential contribution of a continuous operations environment to flexible, responsive opportunities for investigators and payload developers. This is critical because discovery cannot always be scheduled and unanticipated outcomes often lead to the most significant breakthroughs. The scientific benefits of the ISS research environment can be more fully realized if the concept of operations aggressively moves from the principles rooted in the limited duration human space flight missions of past programs to take full advantage of the potential of this international asset.

7.1 Case for Change Guided by a Long-Term Plan for Operations

The current ISS concept of operations, the requirements that govern the concept, and the processes and systems that support it are staffed, operated, and maintained by skilled and dedicated people adhering generally to well-established and proven practices and templates. A significant effort has gone into the development of this operations concept for ISS payloads and payloads have been supported very successfully during the Assembly Phase. While recognizing the accomplishments, the POCAAS Team believes there are changes that will make long-term payload operations more resource efficient and will move ISS closer to the concept desired by most researchers.

This study has conducted an intensive review of current ISS payload operations and makes recommendations for efficiency improvements and reductions in the costs of operations. Within the limits of the study objectives and the scope and duration of the study, these recommendations concentrate on the near-term and on cost savings. It was also clear in the course of the team discussions, that changes should be made in the ISS concept of operations to take full advantage of the continuous operations environment. Additionally, it became evident in reviewing the design reference missions and the probable technology replacements and upgrades that ISS payload operations will continue to evolve. Progress along the operations learning curves and successful research results will promote further evolution. A plan that will provide a living baseline for evaluating and implementing specific changes and continuous improvement would be extremely beneficial in guiding process, technology and staff skills development, and change.

The formulation of a long-term plan was not possible within the context of this study, but the areas where the change initiatives should be concentrated are discussed within this Section.

7.2 The Advantages of Continuous Operations

The basic advantages of the continuity available in ISS operations can best be seen in a comparison to the operational characteristics of the Space Shuttle, Spacelab, and SpaceHab sortie-type research missions. Long-duration missions also present operations planning and integration challenges as seen in Exhibit 7-1.

Exhibit 7-1. Key Operational Characteristics

Sortie (Increment)	Long-Duration Missions
Concept that all payloads are new for each increment	Concept that majority (75%) of payloads are continuing or reflights from previous increments
All payload hardware on increment must be certified for each increment	Payload hardware remaining on-orbit was certified when launched. Review integrity periodically
All payload hardware launched on a flight must be certified for flight	All payload hardware launched on a flight must be certified for flight
Payload crew procedures processed and certified for each increment	Payload crew procedures established when payload launched and maintained through RT operations
Payload displays reviewed and certified for each increment	Payload displays reviewed and certified when payload launched and maintained through RT operations
PODF new for each increment	PODF maintained through on-orbit configuration control
Crew change-out regarded as beginning new mission	Crew change-out regarded as shift handover for on-going payload operations
Payload documentation system based on separate documents for each increment	Payload documentation system based on one-time baselining with change control for reflight
In-depth planning on increment basis	Relaxed planning
Infrequent reflight opportunities	Ability to repeat payload operations
Training designed for specific flight crew	Training designed for generic flight crew

While time on orbit will always be an expensive and precious commodity, the less time constrained environment of the ISS offers the ability to conduct most space research without undue external pressure as to the time required to set up and conduct the experiment and then react to the immediate results or indications. Resolution of anomalies or reaction to unexpected results can proceed at a more deliberate pace. If reflight is indicated to improve processes or equipment, or if results prompt the researcher to pursue a variation or second-generation alternative based on results, the opportunities for reflight are greatly improved.

Human space flight payload operations have been marked by minute-by-minute intensive planning and timelines that are intended to maximize the return from the time available. Often these precise plans and procedures must be revised in real-time to adjust to the mission as it unfolds, to handle systems occurrences, or to take advantage of "discoveries". The resources that have gone into this intensive planning for sortie missions are significant. The processes have required a level of data specificity and detailed interaction with users that are a source of considerable concern when extrapolated to a large number of experiments flown over long durations. With the continuous operations environment of ISS, the researchers and the crew have the time and will benefit greatly from the opportunity to plan and adjust more of their detailed schedules and activities based on their evaluation of the situation and priorities. The preflight and real-time ground planning can be on a higher, more relaxed level.

In the continuous operations environment, a payload mission can span more than one increment and, therefore, be operated or serviced by more than one increment crew. Training must, therefore, shift from concentration on a specific flight crew or crew member to a generic crew approach that provides general preparation for multiple crews.

Along with the advantages inherent in the ability to repeat operations during flight, and to fly repeat or second-generation experiments promptly there are inherent challenges. The operations integration and planning processes must be adjusted to accommodate late manifesting when the decision is made to expeditiously fly repeat or second-generation payloads and planning must cope with the probable delay in other experiments when there is significant carry-over work for an ongoing payload.

7.3 The Payload Operations Vision in Practice

The three major elements of the operations vision for the ISS were described in Section 2.1. The operations concept features that are needed to make those vision elements a reality can be defined as follows:

- **Facilitate the pursuit of flight research and make the complex operation environment associated with the ISS transparent to the end-user.** There are two possible approaches. The first approach would be to use NASA resources to totally buffer the researcher and payload developer from the complexities of the current complex environment. The second approach, and the only affordable approach, is to reduce the complexity and streamline the processes wherever possible. Alternative operations service levels and processes should be provided so that a payload must deal with only those requirements that apply. Total transparency to the user is an unrealistic goal, but significant process improvement and limited but effective assistance when necessary can produce a user-friendly and more affordable environment.

- **Make the researcher fully responsible for the success of his/her experiment, and enable the researcher to interact with his/her experiment apparatus as nearly as possible in the same way that he/she would interact in a remote Earth laboratory.** Quite simply, for a given payload, this means removing as many as possible of the current tiers of requirements, people, and functions between the researcher and the onboard experiment. This will be difficult because the NASA program and operations personnel feel that they have always been held accountable for payload mission success in addition to their mandatory (and continuing) responsibility for safety. They will understandably be reluctant to dispense with the checks and balances of the current operations concept. But for ISS, it is time to recognize the researcher's mission success responsibility.

- **Facilitate the researcher's conduct of science at the minimum possible cost, consistent with the objectives of maintaining crew and ISS safety and protecting each payload from damage or interference from other payloads.** This statement captures the basic challenge of ISS payload operations support; i.e., provide the necessary services and support at the lowest possible cost consistent with protecting the crew, the

ISS, and the individual and collective integrity of payloads. This is the implementation test for process and concept restructuring proposals.

7.4 Recommended Changes for Continuous Operations

The POCAAS Team believes that ISS payload operations can be further streamlined resulting in a reduced workload for the researcher and the payload developer and, just as critical to overall program cost reduction, a reduction in the resource requirements for NASA operations support. Any significant process streamlining and cost reduction must be accompanied, in fact driven, by reevaluation, streamlining, and reduction of program requirements, standards, and payload integration activities. Changes that are recommended for implementation in continuous operations are as follows:

- **Relax resource utilization and preflight/real-time planning optimization.** The flexibility, the less time-constrained environment, and the ability to repeat operations inherent in continuous operations make intensive and optimized planning unnecessary and not sufficiently value-added to warrant the resource expenditure. It is recommended that the level of detail and the number of iterations in the planning process, particularly in the early portion of the payload template, be thoroughly scrubbed.

- **Increase the use of real-time operations versus preplanning.** The ISS payload operations do not require predetermined minute-by-minute plans that optimize the research that can be accomplished in a tightly time-constrained flight duration. That pace is not sustainable in a continuous operations environment and unrealistically constrains the researcher and crew in what is intended to be a true laboratory setting. More productive science will undoubtedly result from real-time flexibility on priorities and plans that respond to the situation.

- **Build and adapt operations concepts and practices incrementally during ongoing operations.** A hallmark of NASA mission operations has been the capability to respond to mission changes, anomalies, and emergencies. This has been the result of the skill, training, and team approach of the operators and support staff. As this level of expertise and operations know-how matures in the ISS payload operations, the confidence level and management change control processes can support continuous improvement in operations concepts and practices during ongoing mission activity. Obviously, any changes will now be occurring during ongoing operations. This recommendation is not primarily directed at changes that can be extensively modeled and simulated prior to first use during a future increment. This recommendation applies to the flying of payloads with sufficiently mature operations concepts and procedures to initiate operations but with the intention of further developing elements of the concept and making procedures improvements as the mission progresses. Taking advantage of real-time experience and results is a basic advantage of the ISS research environment.

- **Increase the use of self-paced, onboard crew training and Help facilities.** The possibility of an extended length of time between the crew's last training on a payload before launch and the in-flight execution of nominal or malfunctions procedures results in the need for a means of "refreshing" the crew's training. This makes the use of onboard training and payload operations Help facilities an important element of the program. Fortunately, the advances in computer-based training and video training delivery provide these capabilities and the program is taking advantage of them. Further advantages can be pursued by using these onboard capabilities to make the ground training more efficient and to replace all or portions of the ground training in some cases.

- **Accept less perfection in procedures and displays, because the additional risk of error is acceptable.** Considerable resources and critical personnel and template time can be saved if the present strict requirements are converted to reasonable guidelines on procedures and displays. Only safety-critical procedures and displays should be subject to absolute requirements and then the requirements should address the key functional aspects. The final decision as to the adequacy of the procedures and displays should be deferred to the POIF after appropriate coordination with PI/PD and crew. Reiterations based on individual preferences should be the exception and considered only in response to specific problems.

- **Accept the flight of experiments with operations that have not been fully defined and validated where justified by time criticality.** No experiment should be flown until the total operating envelope has been verified as safe for all nominal, off-nominal, and failure modes of the equipment. This includes all procedures that are necessary to safe the experiment and to protect the ISS and all other experiments. The probability remains that there will be experiments that are safe and have compelling reasons for manifesting on the next flight, but do not have the time to achieve fully defined and validated operations. In these cases, every consideration should be given to flying the experiment.

- **Eliminate the requirement for resubmitting documentation for reflights on successive increments.** It is believed that this is the program's intention and has been put in practice in several instances. This should be a clear program guideline and, where the environments warrant, documentation and certification for other programs should be considered for potential application to ISS. Researchers would welcome this policy and the PI team and the program would save resources and time.

- **Create an incentive for designing modular experiment equipment that incorporates hardware with sample changeout capability.** In certain areas of research, it may be possible to develop experiment hardware that is designed to support continuous operations by allowing sample changeout. The hardware would remain on orbit, thereby reducing the launch and return logistics. Different samples, including samples from totally different researchers, could be installed by the crew and supported by the same equipment. The experiment equipment would be required to provide an increased scope of operating ranges and modes but the interested elements of the user communities could collaborate on the design. This concept has been applied to the larger facilities on the ISS but may increase research productivity without compromise of quality on a smaller scale.

Appendix A. Statement of Work
ISS Payload Operations Concept and Architecture Assessment Study (POCAAS)

Background

The concept of operations for user payloads on the International Space Station (ISS) is largely derived from experience gained over the last 20 years from Space Shuttle missions, which employed Spacelab modules/pallets or, more recently, Spacelab middeck augmentation modules. These missions were limited to less than 20 days due to Space Shuttle and crew flight duration constraints. As a result, the missions were highly optimized during the planning phase and executed around-the-clock with intensive near real-time replanning to maximize the research return from payload operations. In addition, payloads were designed to stringent requirements, at high cost, to ensure research mission success in the severely limited flight opportunity environment.

The ISS era promises near continuous payload operations as the completion of station assembly approaches. Although flight safety remains of paramount concern, the time constraints associated with research operations are significantly different, and the payload logistics problem fundamentally changed—after the ISS is initially outfitted with rack/pallet-scale experiment systems, the resupply of consumables and orbital replacement units (ORUs) becomes of greatest importance to maintaining laboratory and observatory productivity.

The overhead costs represented by these functions have consistently grown in proportion to the direct costs of doing the research. Recent fiscal constraints have necessitated this study to reexamine the costs associated with payload operations.

Period of Performance

Date of award to February 8, 2002

Task Statements

Task 1: The contractor will assess the current ISS concept of payload operations and the associated flight/ground architecture for efficiency improvements. This shall include the following elements:

- Payload Operations Integration Center and Functions (POIC/POIFs)
- Telescience Supports Centers and Functions (TSCs)
- Crew Training Centers and Functions
- Mission Control Centers for each ISS Partner

The contractor should consider prior or existing spacecraft that operate continuously or semicontinuously for applicability to the ISS. The effects of reduced time constraints, changes in logistics demands, rate-limiting resources, or other factors affecting the productivity of orbital laboratories and observatories are to be addressed for relevance.

Task 2: The contractor will recommend the potential for time-phased reductions in the cost of payload operations through the following approaches:

- Efficiency improvements to existing systems
- Interim or permanent changes to existing requirements on systems
- Changes to the current concept of payload operations to most effectively take advantage of continuity in ISS operations

Deliverables

1. Mid-term briefing to NASA management not later than December 1, 2001. The mid-term briefing shall include the status of the study, an estimate of the work remaining, a completion schedule, and any outstanding issues or questions to be addressed by NASA.
2. Final briefing of the findings and recommendations to NASA management not later than January 17, 2002.
3. Twenty-five hardcopies and five electronic copies of the final report due by January 31, 2002. The final report shall include the following types of recommendations:
   a. A description of existing NASA payload operations systems with recommended efficiency improvements
   b. An analysis and recommended interim and permanent changes to current NASA user development requirements
   c. Recommendations on changes to the ISS concept of operations that take full advantage of the continuous operations environment afforded by the ISS

Appendix B. Biographical Sketches of POCAAS Study Team Members

John-David Bartoe, Ph.D.

Current Title: Research Manager, International Space Station Program Office, National Aeronautics and Space Administration

Relevant Experience: Dr. Bartoe is Research Manager for the International Space Station (ISS) at NASA's Johnson Space Center. He provides oversight for the Program Manager concerning the research capability, research hardware, and research plans of the ISS. Prior to his present position, Dr. Bartoe was Director of Operations and Utilization in the Space Station Office of NASA Headquarters from 1990 to 1994. He also served as Chief Scientist for the Space Station from 1987 to 1990. Before coming to NASA Headquarters, he flew on Space Shuttle Mission 51-F (July 29 to August 6, 1985) as a civilian Navy payload specialist. A physicist by training, Dr. Bartoe was co-investigator on two solar physics investigations aboard this mission, designated Spacelab 2, that were designed to study features of the Sun's outer layers. In completing this flight, Dr. Bartoe traveled more than 2.8 million miles in 126 Earth orbits and logged more than 190 hours in space. From 1966 to 1988, Dr. Bartoe worked as an astrophysicist at the Naval Research Laboratory in Washington, D.C., and published more than 60 papers in the field of solar physics observations and instrumentation

Professional Accomplishments: Dr. Bartoe is a member of the Association of Space Explorers and is Chairman of the Space Station's Committee of the International Astronautical Federation. His awards include the NASA Exceptional Achievement Medal, the Navy Distinguished Civilian Service Award, the Flight Achievement Award of the American Astronautical Society, the NASA Space Flight Medal, and the NASA Skylab Achievement Award.

Education: B.S., physics, Lehigh University (1966); M.S. and Ph.D., physics, Georgetown University (1974 and 1976)

John M. Cassanto

Current Title: Founder of Instrumentation Technology Associates Inc. (ITA), Chief Executive Officer and Chairman of the Board

Relevant Experience: Mr. Cassanto has 25 years' experience with the General Electric Company (GE) in Department of Defense (DOD) missile and reentry vehicle flight test programs, including launch vehicles, orbital free fliers, orbital recovery capsules, reentry vehicles, and DOD satellite integration on the Shuttle. He formed ITA in 1983 to provide commercial space infrastructure elements for private sector space initiatives. He negotiated three separate Commercial Space Act Agreements with NASA for the flight of commercial payloads on the Shuttle. His firm has flown commercial microgravity payloads on eight Space Shuttle flights, eight sounding rockets, one Mir mission, and four Low-G aircraft flights. ITA also developed generic low cost multi-user space processing hardware to reduce the cost of conducting microgravity experiments in space. His company under contract to JSC has developed, fabricated, and tested the MEPS payload scheduled to fly on the UF-2 ISS mission.

Mr. Cassanto has been a vocal supporter of NASA's commercial space initiatives for 20 years and a proponent of space policies to encourage the U.S. private sector to invest in space research.

Professional Accomplishments: Mr. Cassanto was the GE Project Engineer responsible for the company's effort for the design, development, and ground and flight testing of the DOD Minuteman missile nosetip program as well as for meeting milestones on time within budget. He has testified on three occasions before the U.S. House of Representatives Subcommittee on Science, Space, and Technology regarding NASA's commercial space program. His company was the first to successfully demonstrate the feasibility of microcapsulation of drugs technology in space on a commercial sounding rocket, and has sponsored cancer research projects on Shuttle flights. Mr. Cassanto developed a private-sector student space outreach experiment program and has flown student piggyback experiments for more than 30 schools and has interacted with more than 2000 students over the past decade. He has published more than 50 papers dealing with reentry vehicle flight tests, Shuttle microgravity experiments, and various microgravity carriers for orbital recovery capsules and Shuttle applications.

Education: B.S., aeronautical engineering, Pennsylvania State University; "A" course graduate of the GE engineering/management course; and post graduate engineering and management courses, Villanova University

John Cox, Ph.D.

Current Title: Director, Computer Sciences Corporation

Relevant Experience: Dr. Cox has a long career in flight training, flight operations, and program management. He served as Shuttle program flight director; was the utilization and operations manager, deputy program manager, and acting program manager for the Space Station Freedom Program; and was the operations manager on the Space Station redesign team. He served on two National Research Council study teams related to International Space Station (ISS) issues and served as chairman of the CSC-led ISS Operations Architecture Study.

Professional Accomplishments: In the Skylab program, Dr. Cox served as the lead biomedical officer, flight training manager, and flight director; for Space Station, he was the director of utilization and operations, deputy program manager, and acting program manager. He chaired the ISS Operations Architecture Study, served as the operations manager on the original Space Station Operations Task Force study that defined the utilization and operations for the phase A/B program, and served as Code U organizational operations advisor.

Education: B.S., mechanical engineering, University of California at Berkeley; M.S., aerodynamics, and Ph.D., biomedical engineering, University of Houston

Roger K. Crouch

Current Title: Senior Scientist for International Space Station, Office of Space Flight, National Aeronautics and Space Administration

Relevant Experience: Mr. Crouch has been on loan from MIT to NASA Headquarters as the Senior Scientist for the International Space Station since 2000. Prior to that, he was on loan from MIT as the Senior Scientist for the Office of Life and Microgravity Sciences, NASA Headquarters (1998-2000); for crew training, flight, and post-flight activities (1996-1998); and as Lead Scientist of the Microgravity Space and Applications Division (MSAD) (1985-1996).

Mr. Crouch organized and served as co-chair for Microgravity Science Working Groups between NASA and the European Space Agency and space agencies from France, Germany, Japan, and Russia. He was the founding co-chair of the International Microgravity Science Strategic Planning Group consisting of these space agencies plus Canada. He was principal investigator on an experiment that flew in the Materials Experiment Apparatus on the D-1 mission in 1985. As group leader and researcher at NASA Langley Research Center (1962-1985), Mr. Crouch led a research group investigating the effects of convection on semiconductor materials' properties. He was a principal investigator in the MSAD flight program from 1985-1997. This research resulted in the publication of more than 40 technical papers and more than 50 technical conference reports.

Professional Accomplishments: Mr. Crouch was a payload specialist on STS-83 (April 4-8, 1997) and STS-94 (July 1-17, 1997) and has logged more than 471 hours in space. He trained as the alternate payload specialist on STS-42 (First International Microgravity Laboratory), which flew in January 1992. His awards include the Distinguished Alumni Achievement, Virginia Tech, 1998; Distinguished Alumnus 1997, Tennessee Technological University; NASA Exceptional Performance Award, 1989; NASA Special Achievement Award, 1983; and the Floyd Thompson Fellowship, 1979-80. Mr. Crouch has received certificates for patents/ applications in 1975, 1985, 1986, and 1987, and certificates for innovative technology in 1973, 1976, 1979 – 1981, and 1985 – 1987.

Education: B.S., physics, Tennessee Polytechnic Institute (1962); M.S. and Ph.D., physics, Virginia Polytechnic Institute (1968 and 1971); visiting scientist at Massachusetts Institute of Technology in 1979-80

Larry DeLucas, O.D., Ph.D

Current Title: Director of the Center for Biophysical Sciences and Engineering

Relevant Experience: Dr. DeLucas served as Chief Scientist for the International Space Station at NASA Headquarters and as a crew member (payload specialist) on STS-50, Microgravity Laboratory-1 Spacelab mission. He received the NASA Research Award for the research hardware patent entitled "Protein Crystal Growth Vapor Diffusion Apparatus for Microgravity." His professional affiliations have included the following: member, Scientific Advisory Board, National Space Development Agency of Japan; Chair, Science Advisory Board, Diversified Scientific, Inc.; member, Board of Trustees, Illinois College of Optometry; member, SPACEHAB Science Advisory Board; member, NASA Space Station Science Utilization and Advisory Subcommittee; member, U.S. Space and Rocket Center Advisory Committee; member, American Institute of Aeronautics and Astronautics (AIAA) Space Processing Technical Committee; member, graduate faculty, University of Alabama at Birmingham; member, NASA Science Advisory Committee for Advanced Protein Crystal Growth; professor, Department of Optometry, University of Alabama at Birmingham; Director, Center for Biophysical Sciences and Engineering, University of Alabama at Birmingham.

Professional Accomplishments: Dr. DeLucas has published more than 100 research articles and co-authored two books; he was the co-inventor of 25 patents and a crew member on STS-50.

Education: B.S. and M.S., chemistry, University of Alabama at Birmingham; B.S., physiological optics, University of Alabama at Birmingham; O.D., optometry, and Ph.D., biochemistry, University of Alabama at Birmingham

Dale L. Fahnestock

Current Title: Goddard Space Flight Center Account Manager, Computer Sciences Corporation

Relevant Experience: Mr. Fahnestock has more than 32 years of NASA experience at Goddard Space Flight Center (GSFC), which included positions as former Director, Mission Operations and Data Systems; Deputy Director, MO&DSD; Chief, Information Processing Division; and Chief, Mission Management Office. He headed the major NASA organization in providing complete end-to-end ground system services, including the worldwide ground network, Tracking and Data Relay Satellite System (TDRSS) network, NASA Communications (Nascom) worldwide communications, control centers and mission operations, flight dynamics, data processing, and data product generation for hundreds of experimenters worldwide for many unmanned spacecraft missions, STS, Spacelab, and international agencies. He spent 6 years in industry as an account manager and developer of operations concepts and architectures for NASA spaceflight operations.

Professional Accomplishments: Mr. Fahnestock was the recipient of the NASA Outstanding Leadership Medal. As Chairman of the interagency Network Control Group, he achieved agreements to utilize worldwide tracking and data acquisition assets, led the activity to develop the first catalog of all U.S. tracking and data assets; led the development and completion of ground systems for more than 100 missions and supported all missions successfully at launch on schedule; and reviewed and certified ground system and communications readiness for many STS missions. As Chairman of the Space Network Interoperability Panel (SNIP), he achieved agreements for the European Space Agency’s and the National Space Development Agency of Japan’s space network compatibility with TDRSS.

Education: B.S., electrical engineering, Newark College of Engineering; graduate studies, University of Maryland and New Jersey Institute of Technology; graduate, Defense Weapons Management School at Wright Paterson Air Force Base

Owen Garriott, Ph.D.

Current Title: Research Professor at the University of Alabama in Huntsville, Alabama

Relevant Experience: Dr. Garriott served as the science-pilot of the second manned Skylab mission. His experiment responsibilities included extensive solar observations and studies of effects of extended weightlessness on humans. He repaired six gyros, nine experiments, operational equipment items, and installed a twin-pole solar sunshade as part of an extra-vehicular activity (EVA). He was a Mission Specialist on the Spacelab-1 flight with the European Space Agency lab, and served as Deputy Director and Acting Director of Science and Applications and as the Project Scientist for Space Station at NASA/Johnson Space Center. After leaving NASA, he served as Vice President for Space Programs at an aerospace contractor and was a key team member that developed the International Space Station Operations Architecture Study.

Professional Accomplishments: Dr. Garriott totaled over 13 hours in three EVAs on Skylab and received many recognitions, such as the NASA Distinguished Service Medal, Goddard memorial trophy, and NASA Space Flight Medal. He taught electrical engineering at Stanford University for 4 years before joining NASA.

Education: B.S., electrical engineering, University of Oklahoma; M.S. and Ph.D., electrical engineering, Stanford University; completed 1-year flight training with the United States Air Force, receiving pilot qualification in jet aircraft; Honorary Doctor of Science, Phillips University

Gerald Griffith

Current Title: Senior Engineer, JAMSS America, Inc.

Relevant Experience: Mr. Griffith's experience includes training instructor [flight dynamics for Gemini and Apollo Mission Control Center (MCC) operations], MCC controller on Apollo and Skylab in experiment operations; technical consultant to chief, Astronaut Office, in payload interfaces and crew safety; and 10 years as Astronaut Office representative to the Payload Safety Review Panel. Currently he is supporting National Space Development Agency of Japan activities on the International Space Station (ISS).

Professional Accomplishments: Mr. Griffith is a recognized expert and advocate for crew safety; he led experiment support efforts for flight operations teams during Apollo and Earth resources team on Skylab and has had a key role in streamlining/evolving Shuttle and ISS payload safety review processes.

Education: B.S.M.E., Texas A&M University; M.S.M.E., University of Illinois; postgraduate work, Public Administration, University of Houston

Robert K. Holkan

Current Title: President and Chief Executive Officer, MTS Global, Inc.

Relevant Experience: Mr. Holkan's 34-year NASA career includes experience in flight control, training, facilities, and management at Johnson Space Center.

As Chief, Simulation Operations and Technology Division, Mr. Holkan was responsible for operations and development of the Shuttle Mission Simulator, Space Station Training Facility, and all part-task trainers.

Prior to this, Mr. Holkan was Assistant Director for Facilities for the Mission Operations Directorate, which included development and operations of flight simulators, flight software reconfiguration, and the Mission Control Center. Mr. Holkan also served as Chief, Training Division responsible for development and execution of Space Shuttle astronaut training for vehicle systems and payloads. As Chief, Astronomy Experiments Section, Mr. Holkan provided training to the Skylab I crew on solar experiments.

Additional activities included leading cross-organizational teams in the development of strategic plans for the Mission Operations Directorate, leading a Systems Engineering team to establish the design of the Space Station Training Facility, and leading a review team assessing the performance of Space Station contracts on a programwide basis.

Professional Accomplishments: Honors received by Mr. Holkan include the JSC Certificate of Commendation and the NASA Exceptional Service Medal. He is a member of the Clear Lake Area Economic Development Foundation and serves on their Small Business Committee.

Education: B.S., math and chemistry, Southwestern State University; postgraduate courses: math, University of Oklahoma, and management, University of Houston

Fletcher Kurtz

Current Title: Director, High Performance Computing Center of Excellence, Computer Sciences Corporation

Relevant Experience: Mr. Kurtz served as program manager and chief engineer of the Huntsville Operations Support Center, including the Spacelab Payload Operations Center and the Space Station Payload Operations Integration Center. He supported operations definition and implementation for the HEAO, Hubble, and Chandra free-flying observatories. He has 32 years' experience at NASA and 10 years' in industry, including experience as chief technologist for information technology, business process reengineering for the States of Florida and Alabama, and business unit manager. Currently Mr. Kurtz is consulting for the Marshall Space Flight Center on the Payload Operations Integration Center cost-reduction study.

Professional Accomplishments: Mr. Kurtz's professional accomplishments include Director, High Performance Computing Center of Excellence for CSC; vice-president, Computer System Integration for Nichols Research Corporation; program manager, U.S. Air Force Aeronautical Systems Center Major Shared Research Center; and key advisor and contributor, International Space Station Operations Architecture Study.

Education: B.A., physics, Vanderbilt University; M.A., physics, Vanderbilt University; graduate studies, University of California at Berkeley and University of Alabama Huntsville

Charles Lewis

Current Title: Consultant

Relevant Experience: Mr. Lewis served as chief of the Marshall Space Flight Center (MSFC) Mission Training Division, where he was responsible for flight crew and ground support training for Spacelab and Space Station payload operations, and for integration and development of man-systems design standards. As Deputy Chief, MSFC Mission Engineering Division, he had responsibility for planning, direction, coordination, and leadership of engineers and support personnel for flight operations, operations planning and analysis, flight and ground crew training, and man-systems integration. As the Primary Spacelab 1 Crew Training Coordinator, he developed the initial Spacelab payload crew training approach for international multidisciplinary scientific experiments.

Professional Accomplishments: Mr. Lewis' professional accomplishments include Division Chief, operations training for Spacelab and Space Station; Spacelab training coordinator; Spacelab 1 ground communicator; member of the original Space Station Operations Task Force; crew systems development and simulation support of Skylab extra-vehicular activity systems, including the twin-pole solar shield and solar array deployment.

Education: B.S., electrical engineering, Detroit Institute of Technology

Byron K. Lichtenberg, Sc.D.

Current Title: Consultant

Relevant Experience: Dr. Lichtenberg founded Payload Systems, Inc. He provided hardware and flight support for the MODE and MACE experiments for the Space Shuttle. Payload Systems, Inc., was the first commercial user of the MIR Space Station. He was an investigator for MIT/Canadian Vestibular experiments on Spacelab 1, Spacelab D-1, and Spacelab SLS-1 and SLS-2, and co-principal investigator for the Mental Workload and Performance experiment assessing human-computer workstation characteristics for the Space Station. Dr. Lichtenberg was a payload specialist on the ATLAS-1 Spacelab mission (9 days in 1992) and the Spacelab-1 mission (10 days in 1983); he conducted multiple experiments in life sciences, materials sciences, Earth observations, astronomy and solar physics, and upper atmosphere and plasma physics.

Professional Accomplishments: Dr. Lichtenberg's professional accomplishments include founding member, Association of Space Explorers; member, User Panel for National Space Biomedical Research Institute; member, National Research Council Committee on Engineering Research and Technology Development on the International Space Station; member, NASA Task Force on the Scientific Uses of Space Station; and recipient of the NASA Spaceflight medal, the AIAA Haley Spaceflight Award, and the FAI Komorov Award.

Education: Sc.D., Westminster College (honorary); Sc.D., biomedical engineering, MIT (1979); S.M., mechanical engineering, MIT (1975); Sc.B., aerospace engineering, Brown University (1969)

John O'Neill

Current Title: Consultant

Relevant Experience: Mr. O'Neill was the first director and organizer of the Space Operations Office, which provides Agency-wide mission and data services. He was Director of Mission Operations at the Johnson Space Center (JSC) (1994 – 1996) and Deputy Director for 7 years prior. He has 34 years' total NASA operations experience. Mr. O'Neill led preflight planning, training, and real-time flight control of NASA human space flight missions and payload operations; developed operations concepts as a member of the Space Station Redesign Team; and was instrumental in the evolution of the facilities and systems involved in mission development and support.

Professional Accomplishments: Mr. O'Neill's NASA operations experience spans the Gemini, Apollo, Apollo-Soyuz, Skylab, and Shuttle programs and early Space Station development. He was Chief, Payload Operations Division during formulation of Shuttle payload operations processes.

Education: B.S., mechanical engineering, University of Nebraska; M.S., mechanical engineering, University of New Mexico; Program for Management Development, Harvard Business School

Ron Parise, Ph.D.

Current Title: Researcher, Internet in Space, Computer Sciences Corporation

Relevant Experience: Dr. Parise, while working at Operations Research Inc. upon graduation in 1979, was involved in developing avionics requirements definitions and performing failure mode analyses for several NASA missions In 1980 he began work at Computer Sciences Corporation (CSC) in the International Ultraviolet Explorer (IUE) operations center as a data management scientist and in 1981 became the section manager of the IUE hardcopy facility. In 1981 he began work on the development of a new Spacelab experiment called the Ultraviolet Imaging Telescope (UIT). His responsibilities involved flight hardware and software development, electronic system design, and mission planning activities for the UIT project

In 1984, NASA selected him as a payload specialist in support of the newly formed Astro mission series. During his 12 years as a payload specialist, he was involved in mission planning, simulator development, integration and test activities, flight procedure development, and scientific data analysis, in addition to his flight crew responsibilities for the Astro program. A veteran of two space flights, Dr. Parise has logged more than 614 hours and 10.6 million miles in space. He served as a payload specialist aboard STS-35 in 1990 and STS-67 in 1995.

STS-35/Astro-1 Columbia (December 2-10, 1990). The Astro observatory is a unique complement of three telescopes designed to simultaneously record spectral data, polarimetric data and imagery of faint astronomical objects in the far ultraviolet. Mission duration was 215 hours and 5 minutes. Landing was at Edwards Air Force Base in California. c*STS-67/Astro-2 Endeavour (March 2-18, 1995).* This was the second flight of the Astro observatory. During this record-setting 16-day mission, the crew conducted observations around the clock to study the far ultraviolet spectra of faint astronomical objects and the polarization of ultraviolet light coming from hot stars and distant galaxies. Mission duration was 399 hours and 9 minutes. Landing was at Edwards Air Force Base in California.

At the completion of the Astro program, Dr. Parise assumed an advanced planning and communications engineering support role for a variety of human spaceflight projects including Mir, International Space Station, and the X-38. Dr. Parise has engaged in a number of astronomical research projects utilizing data from ground-based observatories, the Copernicus satellite (OAO-3), IUE, and the Astro observatory. His research topics, including circumsteller matter in binary star systems and the evolutionary status of stars in globular clusters, have resulted in several professional publications.

Currently, Dr. Parise is supporting the Goddard Space Flight Center, Networks and Mission Services Project, in the area of advanced communications planning for human spaceflight missions. He is also involved with projects in the Advanced Architectures and Automation Branch that are developing the use of standard Internet Protocols in space data transmission applications.

Professional Accomplishments: Dr Parise is a member of the American Astronomical Society, Astronomical Society of the Pacific, Association of Space Explorers, International Astronomical Union, Sigma Xi, and Phi Kappa Phi. He has twice been awarded the NASA Space Flight Medal, in 1991 and 1995. Other honors bestowed on him include distinguished member of Phi Kappa Phi, 1996; Honorary Doctor of Science, Youngstown State University, 1996; NASA/GSFC Special Act Award, 1995; CSC, Space and Earth Technology Systems, Award for Technical

Innovation, 1999; NASA Group Achievement Award, 1988, 1991, 1992, 1996, 1998, 2000; NASA/GSFC Community Service Award, 1990; and Allied Signal, Quest for Excellence Award, 1997.

Education: B.S., physics, with minors in mathematics, astronomy, and geology, Youngstown State University, Ohio (1973); M.S. and Ph.D., astronomy, University of Florida (1977 and 1979)

Edward Pavelka

Current Title: Consultant

Relevant Experience: Mr. Pavelka has a broad range of expertise in trajectory planning, management (for Apollo, ASTP, and Shuttle flights), and Mission Control Center operations support, operations planning, payload operations, flight planning, and facilities development. He served as Chief, Operations Division, responsible for operations and planning for payload support, flight planning, and trajectory activities for all Shuttle flights, development of payload integration, and integrated cargo hazard assessment processes. Mr. Pavelka has 3 years of experience working with Boeing in assessment of payloads compliance with ISS requirements. He has also supported the United Space Alliance in implementing the Operations Controls Agreement Safety Database (OCAD). He supported the POCAAS CSC study effort as a team member specializing in ISS planning.

Professional Accomplishments: Mr. Pavelka's professional accomplishments include section head, Flight Dynamics; branch chief, Flight Planning; division chief, Operations Division, MOD; deputy assistant director for Shuttle Operations, MOD, and USA project lead, Operations Controls (Safety).

Education: B.S., aerospace engineering, University of Texas at Austin; graduate studies at The University of Houston, Clear Lake, related to the JSC Management Development Program

Tom Recio

Current Title: Consultant

Relevant Experience: Mr. Recio has 25 years' experience in manned and unmanned payload operations planning and execution. He served as operations manager for the Einstein Observatory, was Payload Operations Director for the SL-1 mission, and Chief of the MSFC Operations Integration Office. He lead the team that performed the operations reengineering study for the Hubble Space Telescope Science Institute. Mr. Recio has 6 years' experience in industry in payload hardware development, payload integration, and utilization support for the International Space Station, and has been Deputy Manager of the Payload Utilization Contract.

Professional Accomplishments: Mr. Recio was Manager, MSFC Operations Integration Office and Deputy Manager, ISS Payload Utilization. He was the recipient of two NASA Exceptional Service Medals.

Education: B.S.I.E., University of Florida; graduate studies, University of Alabama in Huntsville

Al Sacco, Jr., Ph.D.

Current Title: George A. Snell Distinguish Professor of Engineering, Northeastern University

Relevant Experience: Dr. Sacco holds the George A. Snell Chair of Engineering and is Director, Center for Advanced Microgravity Materials Processing at Northeastern University. He was the Department Head/Professor at Worcester Polytechnic Institute, Department of Chemical Engineering. Dr. Sacco served as backup payload specialist on STS-50, a payload specialist on STS-73, and principal investigator and payload developer for the Zeolite Crystal Growth experiments. He has performed as a consultant in the fields of catalysis, solid/gas contacting, and equipment design for space applications. He lead the Science and Technology Working Group to evaluate NASA's Advance Life Support Program.

Professional Accomplishments: Dr Sacco was the principal investigator for STS-50, STS-57, STS-73, and UF-1 and 8A. He has been published more than 150 times in the areas of carbon filament initiation and growth, catalyst deactivation, and zeolite synthesis and microgravity materials processing. He received the Admiral Earl award for meritorious contributions in applied sciences before age 35. He is a member of the Worcester Engineering Society and the International Academy of Astronautics, is an elected fellow of the AIChE, has received the NASA Space Flight Medal, and was awarded the Christy McAuliffe Outstanding Teacher Medal.

Education: B.S., chemical engineering, Northeastern University; Ph.D., chemical engineering, MIT; two honorary doctorates of engineering (Northeastern University and Worcester State College) and one honorary doctorate in science (Worcester Polytechnic Institute)

Carl Shelley

Current Title: Chief Engineer, JAMSS America, Inc.

Relevant Experience: Mr. Shelley has flight operations experience at NASA Johnson Space Center (JSC) on all of the manned spaceflight programs, including flight crew and flight controller training, flight control team operations, crew procedure development, flight planning, and payload operations. He was deputy director of MOD; manager of the Space Station Freedom program utilization activities for 2 years; deputy manager of JSC Space Station Projects Office (5 years); assistant manager, Space Shuttle Program (4 years); and is currently chief engineer, JAMSS America, Inc., supporting National Space Development Agency of Japan activities on the International Space Station.

Professional Accomplishments: Mr. Shelley co-chaired the Space Station Operations Task Force study in 1987, which originated the Payload Operations Integration Center concept. He served as deputy project manager for SSF work package 2 development. Mr. Shelley provided Shuttle Program management planning and implementation for the Space Flight Operations Contract awarded to United Space Alliance. He was an advisor on and contributor to the International Space Station Operations Architecture Study.

Education: B.S., electrical engineering, Auburn University; postgraduate courses, electrical engineering, University of Southern California and University of Houston

Jerry Weiler

Current Title: Senior Analyst, Morgan Research Corporation, Huntsville, Alabama

Relevant Experience: Mr. Weiler was Chief, Mission Planning Division, Marshall Space Flight Center (MSFC). He has experience in design and operation of mission planning systems, as well as in the conduct of analysis and planning of space missions. He served as payload activity planning officer for Spacelab missions, and designed and developed the MSFC Mission Integrated Planning System. He currently is performing independent verification and validation (IV&V) of the International Space Station Payload Planning System.

Professional Accomplishments: Mr. Weiler has NASA experience in Apollo, Skylab, Spacelab, and Space Station operations and software development. He was the Payload Activity Planner for Spacelab Missions and the Mission Integration Branch Chief and Chief, MSFC Mission Planning Division.

Education: B.S., University of Alabama; graduate studies, University of Alabama at Huntsville

Appendix C. Researcher Survey

This appendix provides detail regarding the researcher survey whose results were discussed in Section 2.4 of this report. The appendix contains four parts:

1. A narrative description of the survey and detailed analysis of its results.
2. A copy of the survey questionnaire
3. A listing of the addresses of the questionnaire
4. A compilation of the comments received in response to the questionnaire.

Appendix C
Part 1. Survey Description and Analysis

C.1 Researcher Perspectives

The active researchers on the POCAAS Team identified a number of issues that they believe cause unnecessary cost for ISS research and inhibit researchers who would potentially use the ISS as a research facility:

- Current ISS payload practices (not confined to payload operations) are resulting in a document burden on the principle investigators that is significantly greater than for Spacelab or other past human space missions.
- The ISS Payload Data Library requires excessive researcher effort to maintain and is not always used by the NASA Payload Operations personnel
- ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to unnecessary degree
- ISS Payload operations planning and execution practices are overly formalized with multiple approval levels
- Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily.

C.1.1 Researcher Issue Validation Survey

At the request of NASA, the study team assembled a brief questionnaire to test the validity of these issues, identify any additional issues, and gather any recommendations on how to address the issues. A copy of the questionnaire assembled by the POCAAS study team is included in this appendix.

The following sections describe the questionnaire survey, data, and results in more detail.

C.1.2 Method and Respondents

The researcher issues identified by the POCAAS team were used, as is, for the content of the questionnaire. All 61 researchers listed with the ISS research office who were participating in ISS research through increment 6 were invited to respond by rating their level of agreement with each issue according to the following scale:

- 0=Insufficient direct knowledge or experience on which to base a response
- 1=Strongly Disagree
- 2=Somewhat Disagree
- 3=Somewhat Agree
- 4=Strongly Agree

The scale was developed to provide a forced-choice response set, but allow for the likelihood that the respondent may judge they had insufficient knowledge to respond to a particular question. Respondents were invited to provide comments or recommendations to each issue and were assured that their responses would be handled confidentially. Prior to sending out the questionnaire and in some of the responses, there was some comment that the questions/issues were negatively cast. In the background and instructions section of the questionnaire, we acknowledged this situation calling it to the awareness of the respondents and asking them not to be influenced by the questions' formulation. Dr. John-David Bartoe, NASA ISS research manager, served as the named point of contact. The questionnaires were sent in his name and responses were returned to him.

C.1.3 Respondent Characteristics

We received 37 responses for a response rate of 61 percent, which is a much higher-than-expected response rate. By design, there were no attempts made to contact or follow-up nonresponders. The number of respondents distributed across RPO and Headquarters organizations is shown in Exhibit C-1.

Exhibit C-1. Distribution of POCASS Researcher Questionnaire Respondents by Codes

Position	Summary	RPO					Headquarters Code				
		FB	HLS	MRPO	OSF		M	UB	UF	UG*	UM*
PI	18	3	7	7	1		1	8	2	6	2
PD	11	1	0	5	5		5	0	1	3	2
Both	8	0	1	3	4		4	1	0	2	1
Total	37	4	8	15	10		10	9	3	11	5
*One PI worked with both code UG and UM											

At the time the questionnaire was sent out, Increment 4 was flying on the ISS. The following represent the ISS-flight/increment-related experience of the 37 respondents. Of the 37 respondents

- 23 had payloads flying during Increment 4
- 7 were flying a payload on ISS for the first time during Increment 4
- 19 had flown more than increment by Increment 4
- 6 will fly their first ISS payload on Increment 5 or 6
- 24 had flown payloads on at least one increment prior to Increment 4
- 22 will have flown multiple increments by Increment 6

C.1.4 Data Analysis

The choices made around question construction, and population sampling and survey procedures warranted the use of simple analytical statistics such as descriptive statistics, t-tests, and one factor analysis of variance (ANOVA). Consider the results as indicative of trends and "pointers" to areas and topics requiring further explanation and clarification.

For the quantitative data analyses of the ratings, ratings of "0" (insufficient direct knowledge or experience on which to base a response) and the quantitative data from 5 additional questionnaires received from other associates/team members of the PIs/PDs invited to respond were excluded from the computations. The qualitative response analysis not only included the 79 comments/recommendations received from 23 respondents, but also an additional 20 comments received from the same 5 associates/team members of the PIs/PDs invited to respond.

The data analysis was structured as followed:

1. Determine the overall level of agreement/disagreement to each of the identified issues and the intensity of the agreement/disagreement.
2. Determine if there were any non-random differences in rating patterns among the PI, PD, and both PI & PD groups of researchers that would require further investigation and indicate a difference in the experience of payload operations for a particular subset of the researcher community.
3. Determine the nature of the ratings distributions for each of the identified issues.
4. Identify characteristics that indicate the qualitative aspects of the respondents' experience.

C.1.5 Quantitative Results

C.1.5.1 Overall Level of Agreement

The overall mean rating across the entire issue set was 3.4. This exceeds the rating of 3 (somewhat agree) and indicates a high level of agreement with the set of issues. On a per-question basis, the range of mean ratings was from 3.3 to 3.7.

C.1.5.2 Rating Patterns among PI, PD, and Both Groups

There were no statistically significant differences, F=1.01 (*<Fcrit=3.32),* in overall rating patterns for PIs, PDs, or both (PI/PD). The researcher subgroup a respondent belonged to did not account for their pattern of ratings. Consequently, the ratings across all three groups reflect a consistency of experience of ISS Payload Operations.

ANOVA of Researcher Groups' Ratings

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
PI	14	45.5	3.25	0.79
PD	11	39.6	3.6	0.15
Both	8	28.8	3.6	0.40

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*F crit*
Between Groups	0.99	2	0.49	1.01	3.32
Within Groups	14.64	30	0.49		
Total	15.62	32			

C.1.5.3 Nature of Ratings Distributions for Each Issue

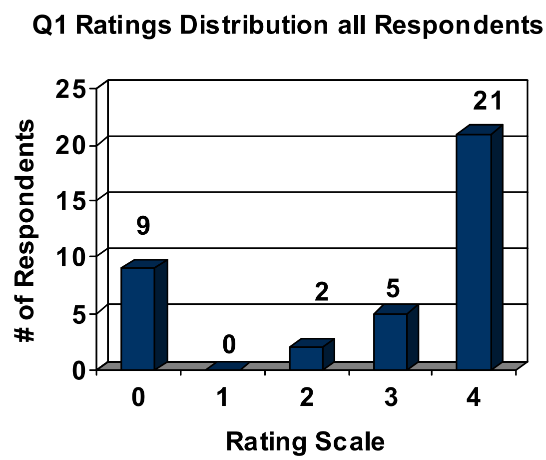
Visual examination of the ratings distributions for each identified issue indicates a high level of agreement for each issue and issue set. While there are differences in the mean ratings, all rating distributions are toward the *strongly agree* side of the rating scale on all questions/issues.

Shown below are the descriptive statistics and ratings distribution charts for each of the five questions/issues.

Question/Issue 1. Current ISS payload practices (not confined to payload operations) are resulting in a document burden on the PIs that is significantly greater than for Spacelab or other past human space missions.

The descriptive statistics summary is shown below.

Descriptive Statistics for Question/Issue #1	
Mean	3.7
Median	4
Mode	4
Standard Deviation	0.61
Range	2
Minimum	2
Maximum	4
Count (n)	28

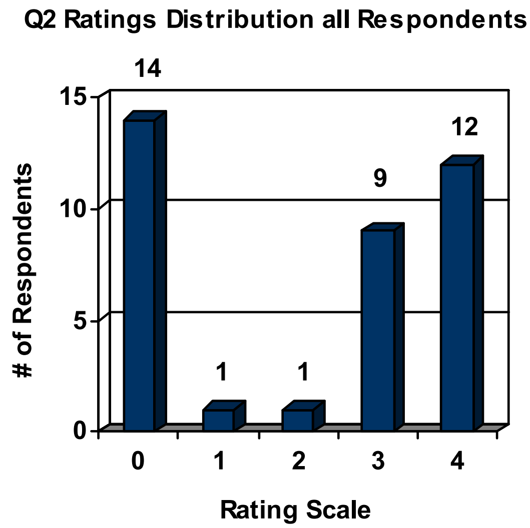


With a mean of 3.7 and a mode and median of 4 indicate that this researcher community considers the current ISS payload documentation requirements excessive. The ratings distribution chart for Question/Issue 1 (Q1 Ratings Distribution all Respondents) visually shows the overwhelming high level of agreement (21 respondents rated this item *strongly agree*, exceeding the *somewhat agree* ratings by a factor of 4) around this issue. *Seventy-five percent of the total number of respondents who had direct knowledge or experience* of the documentation requirements strongly agreed with this question/issue. The other 25 percent of the respondents (9) indicated that they had no direct knowledge or experience of the ISS payload documentation practices on which to base a response.

Question/Issue 2. The ISS Payload Data Library requires excessive researcher effort to maintain and is not always used by the NASA Payload Operations personnel.

The mean rating of 3.4 indicates that there is more than "some" agreement on the maintenance effort required on the part of the researcher and use of the PDL by NASA during payload operations. The descriptive statistics summary is shown below.

Descriptive Statistics for Question/Issue #2	
Mean	3.4
Median	4
Mode	4
Standard Deviation	0.79
Range	3
Minimum	1
Maximum	4
Count (n)	23

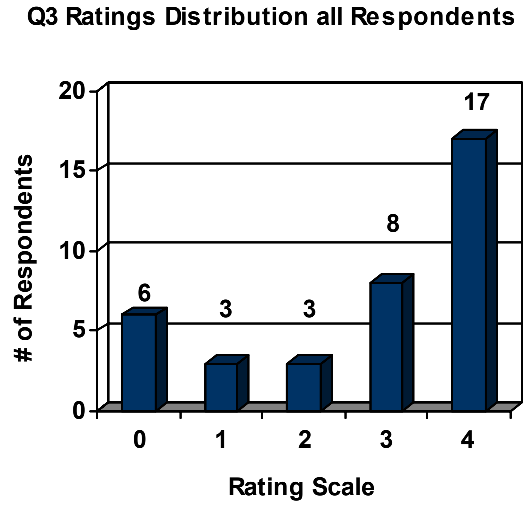


The chart showing the distribution of the respondent ratings (Q2 Ratings Distribution all Respondents) indicates that *38 percent of all the respondents have no direct experience or knowledge* about the PDL and its requirements. This is the largest number of respondents to any of the questions that indicated an absence of experience or knowledge (the next largest number is 9 for Question 1, 8 for Question 5 and then 6 each for Questions 3 and 4.). This number of PIs/PDs who have no direct knowledge of the PDL coupled with the number of researchers who have no direct knowledge/experience with the documentation requirements could indicate there is another research community subgroup that may need to be addressed and included.

The remaining *62 percent of the respondents* (23) with direct knowledge/experience with the PDL, 21 respondents indicate that there is an issue between the level of effort required to maintain it and its use by NASA during operations. In looking at this result, we were directed to the September 2001 report on the customer satisfaction data with version 13.2 software package of the PDL. That survey showed high level of user satisfaction with the revised software program. Conversation with the author of PDL version 13.2 user survey indicated that there is no conflict between his finding and this one. The questions in the 13.2 user survey addressed the user friendliness of the revised software. The question/issue addressed here is not examining the software, but the overall value of the PDL in enabling research to be accomplished.

Question/Issue 3. ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to unnecessary degree.

Descriptive Statistics for Question/Issue #3	
Mean	3.3
Median	4
Mode	4
Standard Deviation	0.99
Range	3
Minimum	1
Maximum	4
Count (n)	31

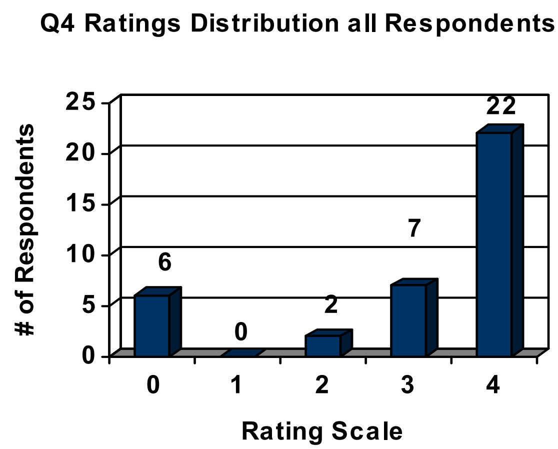


The 3.3 mean rating on this question/issue coupled with the 17 respondents who rated this item "4" and the 8 respondents who rated it "3" (*representing 80 percent of the 31 respondents who rated this question/issue*) fully validates that the enforcement of standards and programmatic requirements appears to the researcher community to be overdone.

This question/issue, along with Question/Issues 4 and 5, had the highest number of total respondents (*n*). Eighty-one percent of the respondents had the direct knowledge/experience to rate this question. The rating distribution chart (Q3 Ratings Distribution all Respondents) continues to show the ratings weighted toward the agreement end of the scale.

Question/Issue #4. ISS Payload operations planning and execution practices are overly formalized with multiple approval levels

Descriptive Statistics for Question/Issue #4	
Mean	3.6
Median	4
Mode	4
Standard Deviation	0.61
Range	2
Minimum	2
Maximum	4
Count (n)	31



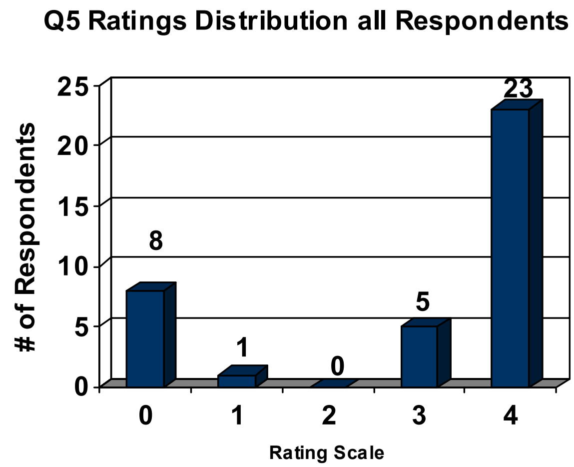
The table below shows the descriptive statistics for this question/issue. High levels of agreement are clear with a mean rating of 3.6 and a mode and median of "4". As with Question/Issue 3, the respondents who rated this question/issue represent 80 percent of the total number of respondents (31 of 37).

The graph, Q4 ratings Distribution all Respondents, shows the number of respondents rating this question/issue a "4", *strongly agree*, exceeds those who rated it a "3", *somewhat agree* by a factor of 3. The number and level of approvals from the researchers' perspective are far too formal and too many

Question/Issue 5. Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily.

This issue was also carried a mean rating of 3.7 with over 23 of the respondents rating this question “4”, *strongly agree*. A mode and median at “4” further supports the strength of the respondents’ ratings.

Descriptive Statistics for Question/Issue #5	
Mean	3.7
Median	4
Mode	4
Standard Deviation	0.64
Range	3
Minimum	1
Maximum	4
Count (n)	29



The ratings distribution pattern shown in the chart below, Q5 Ratings Distribution all Respondents, maintains the direction and is consistent with the ratings to the other questions.

C.1.6 Qualitative Results

Qualitative results were identified through thematic analysis of the content of the respondents’ comments. Over 79 comments were received from 23 respondents. An additional 20 comments were received from 5 associates of the invited respondents. These comments were included in the analysis. A total of 96 comments had substantive content.

Distinct characteristics of the responses included the following:

- Directness of content in terms of identifying situations, systems, processes, and issues that were seen as inhibiting research flight, execution and success and in terms of recommending potential fixes.
- A high level of frustration as illustrated by the comment: “To be honest, it is my sincere hope that I never work for another NASA manned space flight program…”
- A sense that NASA is relearning and not capitalizing on payload operations lessons that were previously learned on Space lab, Shuttle, MIR, and SpaceHab.

C.1.6.1 Overall Themes

The following are the overall themes identified in the researcher comments:

- Drastically simplify ISS documentation requirements on the order of Spacelab, Shuttle, SpaceHab, and MIR requirements. Account for payload reflight that have minimal changes to payload hardware, procedures, content. Reuse existing documentation and documentation from existing sources as much as possible and eliminate conflicts and duplication between functions, programs, and Centers. Bring documentation requirements into line with actual practices/policies of granting waivers and “grand fathering” payloads where appropriate

- The PDL needs to become even simpler to facilitate rapid flight and reflight. Despite the PDL, duplicative, paper-based documentation is often still required. NASA must increase its use of the PDL during operations. PDL is not relevant to life science research and has been waived for some education payloads.

- Standards and programmatic requirements are not focused on researcher needs. Simple experiments must conform to standards and requirements that were designed for the most complex experiments. Experiments that are being reflown are treated programmatically and unnecessarily as first-flight payloads. Specific programmatic requirements related to planning, and timelining are over emphasized and worked in the preflight phase and the products change so rapidly during operations phase that the effort expended in preflight was not worthwhile.

- Lack of direct interaction with the crew puts some payloads at risk. Approval levels and requirements frequently waste valuable researcher-crew time and delays timely execution of an experimental protocol

- There is a strong need for standardized crew procedure development guidance and requirements, for researcher review of final procedures and flexibility in accessing the crew to update a procedure as a consequence of real-time schedule and program changes.

- Customer (researcher) service by the POIC cadre during real-time testing and operations is excellent and accommodating. Such a level of customer service is not pervasive in other elements of the program to include LIS representatives not viewing their function as the focal point for payload information flow, the need for a designated "project coordinator" to interface with the researcher to avoid having too many people making duplicative information requests of the researcher, the splintering in the ISS program with regard to integration and operations.

C.1.6.2 Comment Distribution by Researcher Group

The table below indicates the substantive comment volume by question by researcher group. The greatest number of comments (47) were made by the payload developers suggesting that they have more direct contact with the NASA payloads processes than the PIs might have, particularly some of those who are in the life sciences research discipline and who indicated that they are somewhat more "shielded" from these processes.

Number of Substantive Comments provided by Question by Researcher Group						
Researcher Group with Total number of respondents indicated in Parentheses	**Question 1** 1. Current ISS payload practices (not confined to payload operations) are resulting in a document burden on the Principal Investigators that is significantly greater than for Spacelab or other past human space missions.	**Question 2** 2. The ISS Payload Data Library requires excessive researcher effort to maintain and is not always used by the NASA Payload Operations personnel	**Question 3** 3. ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to an unnecessary degree	**Question 4** 4. ISS Payload operations planning and execution practices are overly formalized with multiple approval levels	**Question 5** 5. Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily	**Total Number of Comments by Group**
PI (18)	5	5	5	5	7	27
PD (11 + 5	10	10	9	9	9	47

Number of Substantive Comments provided by Question by Researcher Group						
Additional Inputs)						
Both PI//PD (8)	5	4	4	4	5	22
Column Totals	20	19	18	18	21	96

Appendix C
Part 2. Survey Questionnaire

Dear Colleague,

As Research Manager for the International Space Station, as well as a former space researcher like you, I am asking your help in answering the five-question survey included below. I too receive n emails per day, where n is a large number. However, this questionnaire will only take 5-10 minutes and your response will be extremely valuable in improving your research experience on ISS in the future.

Please reply no later than Friday, 21 December 2001. If you fill it out right now, the pain will be quickly over!

Thanking you in advance,

Dr. John-David F. Bartoe

ISS Research Manager

Researcher Survey of ISS Payload Operations Planning and Execution

Background: NASA's Office of Biological and Physical research is studying the current ISS approach to payload operations planning and execution in order to make process improvements and cost reductions. The Study Team has identified five potential payload operations issues of concern to researchers and payload developers like you that could help target improvements. We are interested in determining your level of agreement on these five issues, identifying any additional issues, and gathering your recommendations on how to address them.

Instructions: Please complete the following short questionnaire and simply return it by e-mail reply. Please do not let the negative form of the statements influence your answer; we want your personal opinion. Your feedback will be held in confidence.

For each issue, using the scale below, please enter the number in the space provided between the ( )'s that indicates your level of agreement with the statement. Any additional comments or recommendations you might have are very welcome. There are no space limitations.

Scale:

1 = Strongly Disagree
2 = Somewhat Disagree
3 = Somewhat Agree
4 = Strongly Agree
0 = Insufficient direct knowledge or experience on which to base a response.

If you use this choice, please explain why.

The Study Team has identified the following five issues:

( ) 1. Current ISS payload practices (not confined to payload operations) are resulting in a document burden on the Principle Investigators that is significantly greater than for Spacelab or other past human space missions.

Comment/recommendation:

( ) 2. The ISS Payload Data Library requires excessive researcher effort to maintain and is not always used by the NASA Payload Operations personnel.

Comment/recommendation:

( ) 3. ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to an unnecessary degree.

Comment/recommendation:

( ) 4. ISS Payload operations planning and execution practices are overly formalized with multiple approval levels.

Comment/recommendation:

( ) 5. Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily.

Comment/recommendation:

Appendix C
Part 3. Survey Addressees

PIs and PDs on ISS thru Expedition 6
As Used for Survey by POCAAS

ADF (Avian Development Facility)

Principal Investigators

J. David Dickman
Development and Function of the Avian Otolith System in Normal and Altered Gravity Environments
Washington University

Stephen Doty
Skeletal Development in Embryonic Quail
Hospital for Special Surgery

Payload Developer

E-Randall Berthold
Ames Research Center

ADVASC (Advanced Astroculture - Microgravity Impact on Plant Seed-to-Seed Production)

Principal Investigator/Payload Developer

E-Weijia Zhou
Wisconsin Center for Space Automation and Robotics,
University of Wisconsin - Madison

APCF (Advanced Protein Crystallization Facility)*

Principal Investigator/Payload Developer

E-Pasquale DiPalermo
European Space Agency

ARIS-ICE (Characterizing the Active Rack Isolation System)

Principal Investigator

E-Glenn Bushnell
The Boeing Company, Seattle

Payload Developer

E-James Allen
The Boeing Company, Houston

Project Manager

Naveed Quraishi
Johnson Space Center

BBND (Bonner Ball Neutron Detector)

Principal Investigator/Payload Developer

E-Tateo Goka
National Space Development
Agency of Japan

BPS (Biomass Processing System)

Principal Investigators

Tom Crabb
Orbital Technology Corp.

Payload Developer

E-Randall Berthold
Ames Research Center

Photosynthesis Experiment and System Testing Operation Gary Stutte
Dynamac Corporation**CBOSS (Cell Biotechnology Operations Support Systems)**

Principal Investigators

Jeanne Becker
Evaluation of Ovarian Tumor Cell Growth and Gene Expression
University of South Florida

Payload Developer

E-Neal Pellis
Johnson Space Center

Renal Cell Differentiation and Hormone Production from Human Renal Cortical Cells

E-Timothy Hammond
Tulane University Medical Center

Use of NASA Bioreactor to Study Cell Cycle Regulation Mechanisms of Colon Carcinoma Metastasis in Microgravity

J. Milburn Jessup
University of Texas Health Science Center, San Antonio

PC12 Pheochromocytoma Cells: A Proven Model System for Optimizing 3-D Cell Culture Biotechnology in Space

E-Peter Lelkes
Drexel University

Production of Recombinant Human Erythropoietin by Mammalian Cells Cultured in Simulated Microgravity

Arthur Sytkowski
Harvard Medical School

Simulated Microgravity Antigen Synthesis in Tonsillar B Cells

Joshua Zimmerberg
National Institutes of Health

CBTM (Commercial Biotechnology Module)

Payload Developer and PI Interface

E-Ted Bateman
BioServe

CEO (Crew Earth Observations)

Principal Investigator

E-Kamlesh Lulla
Johnson Space Center

CGBA (Commercial Generic Bioprocessing Apparatus) STS 106 sortie

Principal Investigators

E-Timothy Hammond
Neurolab Reflight
Tulane University Medical Center

Payload Developer

E-Louis Stodieck
BioServe Space Technologies

Effects of Spaceflight of Drosophila Neural Development

Haig Keshishian
Yale University

CGBA (Commercial Generic Bioprocessing Apparatus) Increment 2, 4, and 5

Payload Developer and PI Interface

David Klaus
BioServe Space Technologies, Boulder

CPCG (Commercial Protein Crystal Apparatus) *

Principal Investigator

E-Larry DeLucas
University of Alabama, Birmingham

Payload Developer

Dan Connor
University of Alabama, Birmingham

CSLM-II (Coarsening in Solid-Liquid Mixtures II)

Principal Investigator

Peter Voorhees
Northwestern University

Payload Developer

Walter Duval
NASA-GRC

DCPCG (Dynamically Controlled Protein Crystal Growth)

Principal Investigator

E-Larry DeLucas
University of Alabama, Birmingham

Payload Developer

Tim Owen
Marshall Space Flight Center

DOSMAP (Dosimetric Mapping)

Principal Investigator

E-Gunther Reitz
DLR Institute of Aerospace Medicine

DREAMTiME (Long Duration HDTV Camcorder Experiment)

Principal Investigator

Ben Mason
Dreamtime Holdings, Inc

EarthKAM (Earth Knowledge Acquired by Middle Schools)

Principal Investigator

E-Sally Ride
University of California San Diego

Payload Developer

Brion Au
Johnson Space Center

ENTRY MONITORING (Monitoring of Heart Rate and Blood Pressure During Entry, Landing and Egress: An Index of Countermeasure Efficacy)

Principal Investigator

E-Janice Meck
NASA-JSC

EPO (Education Outreach)

Payload Developer

Patience Smith
Johnson Space Center

EPSTEIN-BARR (Space Flight Induced Reactivation of Epstein-Barr Virus)

Principal Investigator

Raymond Stowe
UTMB, Galveston

EVARM (A Study of Radiation Doses Experienced by Astronauts in EVA) Principal Investigator

Ian Thomson
Thomson & Nielson Electronics LTD, Ottawa**ER-EXPPCS (Physics of Colloids in Space)**

Principal Investigator

E-David Weitz
Harvard University

FOOT (Foot Reaction Forces During Space Flight)

Principal Investigator

E-Peter Cavanagh
Pennsylvania State University

MSG/GLIMIT (Glovebox Integrated Microgravity Isolation Technology)

Principal Investigator

Mark Whorton
Marshall Space Flight Center

Payload Developer

Ken Fernandez
NASA-MSFC

H-Reflex (Effects of Altered Gravity on Spinal Cord Excitability)

Principal Investigator

E-Doug Watt
McGill University, Montreal

HRF Rack 1 (Human Research Facility)

Facility Developer

Dennis Grounds
NASA-JSC

InSPACE (Investigating the Structure of Paramagnetic Aggregates from Colloidal Emulsions)

Principal Investigator

Alice Gast
Stanford University

Interactions (Crewmember and Crew-Ground Interactions During ISS Missions)

Principal Investigator

E-Nick Kanas
University of California and
Veterans Affairs Medical Center

MACE-II (Middeck Active Control Experiment-Reflight Program) *

Principal Investigator/ Payload Developer

E-Rory Ninneman
Air Force Research Laboratory, Albuquerque

NASA Interface

Capt Tom Hoge
US Air Force / DoD Space Test Program

MAMS (Microgravity Acceleration Measurement System)

Principal Investigator

E-Richard DeLombard
Glenn Research Center

MIDODRINE (Test of Midodrine as a Countermeasure against Postflight Orthostatic Hypotension)

Principal Investigator

E-Janice Meck
NASA-JSC

MISSE (Materials on International Space Station Experiment)*

Principal Investigator/ Payload Developer

E-William Kinard
Langley Research Center

NASA Interface

Capt Steve McGrath
US Air Force / DoD Space Test Program

MOBILITY (Promoting Sensorimotor Response Generalizability: A Countermeasure to Mitigate Locomotor Dysfunction After Long-Duration Space Flight)

Principal Investigator

E-Jacob Bloomberg
NASA-JSC

MEPS (Microencapsulation Electrostatic Processing System)

Payload Developer and Principal Investigator

E-Dr. Dennis Morrison
Johnson Space Center

MSG (Microgravity Sciences Glovebox)

Payload Developer
E-Charles Baugher
Marshall Space Flight Center

Phantom Torso (Organ Dose Measurements Using a Phantom Torso)

Principal Investigator

Gautam Badhwar-deceased
Johnson Space Center

New Principal Investigator

E-Frank Cucinotta

PGBA (Plant Generic Bioprocessing Apparatus)

Payload Developer
Louis Stodieck

BioServe Space Technologies

Principal Investigators

Alex Hoehn
BioServe Space Technologies

STES (Protein Crystal Growth-Single locker Thermal Enclosure System)*

Principal Investigators

E-Dan Carter
New Century Pharmaceuticals, Huntsville
Facility-Based Hardware Science and Applications

Payload Developer

E-James Branas
Marshall Space Flight Center

Improved Diffraction Quality of Crystals

E-Craig Kundrot
Marshall Space Flight Center

Vapor Equilibration Studies

Aniruddha Achari
Marshall Space Flight Center

EGN (Protein Crystal Growth-Enhanced Gaseous Nitrogen Dewar) *

Principal Investigator

E-Alex McPherson
University of California Irvine

MSG/PFMI (Pore Formation and Mobility Investigation)

Principal Investigator

Richard Grugel
USRA/Marshall Space Flight Center

Payload Developer

Linda Jeter
NASA-MSFC

PUFF (The Effects of EVA and Long-term Exposure to Microgravity on Pulmonary Function)

Principal Investigator

E-John West
University of California San Diego

Renal Stone (Renal Stone Risk During Space Flight: Assessment and Countermeasure Validation)

Principal Investigator

E-Peggy Whitson
Johnson Space Center

SAMS (Space Acceleration Measurement System II)

Principal Investigator

E-Richard DeLombard
Glenn Research Center

SEEDS (Soybean and Corn Seed Germination in Space)

Principal Investigator/Payload Developer

Howard Levine
Dynamac Corporation

MSG/SUBSA (Solidification Using a Baffle in Sealed Ampoules)

Principal Investigator

E-Aleksander Ostrogorsky
Rochester Polytechnic Institute

Payload Developer

Linda Jeter
NASA-MSFC

Stelsys I (Commercial/Proprietary Investigation)

Payload Developer

Thomas J. Goodwin, M.A.
Johnson Space Center

Principal Investigator

Albert Li , Ph.D.
Stelsys, Inc.

Subregional Bone (Sub-regional Assessment of Bone Loss in the Axial Skeleton in Long-Term Space Flight)

Principal Investigator

E-Thomas Lang
University of California San Francisco

Xenon1 (Effect of Microgravity on the Peripheral Subcutaneous Veno-Arteriolar Reflex in Humans)

Principal Investigator

Anders Gabrielsen
National University Hospital,
Copenhagen

ZCG (Zeolite Crystal Growth)

Principal Investigator

E-Al Sacco
CAMMP, Northeastern University

Payload Developer

Nurcan Bac
CAMMP, Northeastern University

Appendix C
Part 4. Compilation of Comments from Survey

The following comments have been edited for clarity. The numbering scheme does not imply any priority, sequence, or respondent.

Question 1. Current ISS payload practices (not confined to payload operations) are resulting in a document burden on the Principle Investigators that is significantly greater than for Spacelab or other past human space missions.

Comments

1.1 "Compared with Shuttle/Mir the computer software design process and training approval process-differing standards at JSC & MSFC, competing committee structures, changing requirements-are more cumbersome & frustrating"

1.2 "…Ratings based on education's experience with Shuttle world."

1.3 "…Major factor regarding burden is that NASA does not have a coordinator and there are a hundred people asking for info…Have a project coordinator for each project."

1.4 "…it is also significantly greater than mid-deck payload…ISS…requirements can be trimmed"

1.5 "…several of the same mistakes that occurred in Spacelab integration happened again…development lack of steady funding results in loss of personnel, starts & stops, unnecessary delays…verification for non-critical requirements is ridiculous….PD & integrator chases documentation for requirements that are not critical to mission success...time line for submitting data...based on when data is needed for stage analyses buildup not where PD is in their hardware development...ISS documentation is becoming pretty good...MPV needs to be fixed or replaced - not user friendly...as a PD I want to report to a single person...EPIMS were helpful, role needs to be expanded into POIF...POIWGs need to become more like old POWG for Spacelab"

1.6 "…Payload XYZ is a very simple, low overhead payload…current station practices have the PIs going to the PDL for the integration agreement, PVP/ICD then to the iURC for resource requirements (again)…how about "one-stop" service eliminating the split between JSC-OZ & MSFC-POIC?"

1.7 "…the current ISS document burden is greater than for Spacelab…it is greater than it needs to be…Some interface requirements are redundant or have conflicting verification requirements…some interface requirements have been put on the PDs that should be the responsibility of the rack administrators...PDs are required to provide the same info/data to multiple documents or databases"

1.8 "...number of POCs & databases is overwhelming to stay current & keep updated…have to have a detailed understanding of MSFC processes and systems…used to have an integration engineer for ops to serve as a single POC to assist w/overall process…"

1.9 “I have only been involved in the Spacelab ___ mission and currently an ISS experiment. Both experiments are pre/post flight with no in-flight portions…the amount of documentation for these experiments has not changed much…I have not been involved with in-flight experiments...”

1.10 “…I have been developing & successfully flying experiments/payloads since 1974 and have never seem it this bad nor as confusing as it is with Payload ops planning & mass confusion with the MSFC as the middleman…We should do business the way Spacehab does...got the job done, with competent people and good help instead of endless process, unreasonable attitudes & chaos.. It now takes 2.6 times more support personnel & cost to REFLY a payload on ISS-Express rack than it cost to develop the original payload & fly it on Shuttle or Spacehab...the unnecessary documentation is not the only issue...Totally eliminate MSFC/Boeing/TBE from payload operations & management support of ISS, cut the total budget by 75 percent & use the funds now being wasted at MSFC to fund bare minimum payload support efforts at KSC & JSC...”

1.11 “JSC human life sciences (Code SF) have a team of people who to some extent "shield" the investigators from the full horror of the ISS paperwork…”

1.12 “Audit & scrub ISS requirements against equivalent Spacelab documentation…pay particular attention to human factors requirements and displays…the documentation has to be re-released or revalidated for each increment even… if the payload is flying without modification or change...”

1.13 “I had absolutely no interaction with the development of documents for the ISS Payload..”

1.14 “Spacelab had an established system and a clear integration process with established integration contractor responsibility. The ISS process has been a work in process with parallel development of early payloads at the same time as the development of ISS utilization capabilities and processes. Many PIRNs are generated by ISS as a result, requiring considerable effort by the PDs to review and respond to potential impacts. The integration process itself evolved and was a moving target”

1.15 “We were a re-flight experiment, having previously flown on STS-XX and we were put through the ringer to fly on ISS. Many of the specs were ludicrous and in the end were waivered after much wailing and gnashing of teeth.”

1.16 “Should refer to Spacehab research missions instead of Spacelab since it is no longer in existence. It is almost impossible to design and develop experiment hardware in parallel with facility/vehicle requirements that are currently being developed or constantly changing. Experiment development teams must therefore devote extensive resources to assess and implement the requirement changes, yet, the ISS program has no mechanism or policy to augment or fund the developer when requirement changes force changes to the experiment. The ISS program with respect to experiment integration and experiment operations is very splintered. To fly an experiment on ISS, a PI/PD team must interface with so many different organizations, it is very easy to get lost in all the requirements, guidelines, schedules, and deliveries. Recommendation: develop an end-to-end user manual for PI/PD teams to fly experiments on ISS.”

1.17 “Needs to be a reassessment in PDL content for data required to fly a payload…”

1.18 “Duplication of data needs to be kept minimal…introduces too much room for error”

1.19 “Reduce the duplicate data inputs. Too many people are asking for the same information and then when it needs updating it is hard to remember who asked for this info and the same old info may exist elsewhere”

1.20 “Payload XYZ was the first payload with which I have worked”

1.21 “…PD is required to enter identical information in multiple places or via e-mail per the request of different groups…there should be one place to enter data…different groups request data in different formats…we spend a lot of time inputting data in different places, but it does not seem that the majority of this data is even used by the program...”

Question 2. The ISS Payload Data Library requires excessive researcher effort to maintain and is not always used by the NASA Payload Operations personnel.

Comments

2.1 “As PI I do not see this PDL at all”

2.2 ”A mild irritant at first-people were responsive and we worked out the kinks”

2.3 “…Education has dispensation from using PDL at this time”

2.4 “By the time one understands how PDL works & where the info is, the hardware is back from the mission”

2.5 “PDL needs to be modified to be user friendly to the PD…PD should not have to enter same info 2x…concept is good implementation of PD side fails…interface should have a single input area…and why is the PD required to enter info like KSC requirements into the system when KSC does not use the system...Two systems cost money that could be used for research!”

2.6 “Bluntly, this is true statement. PDL & iURC data does not flow to all NASA ISS resource controllers…”

2.7 “PDL is well organized…excessive effort to use is caused by the organization of PDL data by flight or increment…since many payloads will operate over several flights organize PDL forms so that launch and return flights are identified and all on-orbit data entered once in the applicable forms that would apply to all flights and increments between launch and return...my impression is that the PDL is referenced very little or not at all during real-time operations...”

2.8 “I do not have primary responsibility for PDL management. Although I understand that it is rather tedious & time consuming…”

2.9 “True, most of the time the payload Operations personnel say they need to information still require separate paper copies of procedures, Cof Cs, drawings, etc…be submitted directly to them…The PDL should be kept only for final document reference, not as the document control mechanism for all changes that occur for the entire 24 months prior to flight. If the documentation for the next flight of the same payload is required there should be a simple way to import the entire PDL file from the previous flight without having to start new submissions all over again just because it is a new increment...”

2.10 “Dealing with the PDL is a nasty experience. This database is poorly suited to life sciences research and seems largely a MSFC invention…the PDL does not really apply (to Life sciences) anyway…principal issue with the PDL is the seeming total inflexibility…we worked around a bug in our downlink spec because fixing it would have required a change to the PDL...”

2.11 “Significant amounts of info in the PDL are not utilized by the program…”

2.12 “I only recently became aware that the PDL existed and I certainly have not utilized it or had any experience with it whatsoever”

2.13 “The potential value for the PDL was to establish a database of payload information that can be shared and used throughout the program without asking the PDs to make multiple inputs. The potential has not been realized”

2.14 “The concept of an electronic database is a great idea but the current system is not PI/PD friendly and often lags significantly behind the continuously changing Program/Vehicle requirements. The library system should be a fixed database for an experiment much like the PIP and annexes systems the Shuttle has used for years. Whenever a P/L is manifested the program should draw from this datafile. For payloads that will fly many times it would be better to have the information by payload then the particular information needed for an increment/flight could be pulled out of this. This would reduce the PD's need to re-enter/copy data for every flight/increment.”

2.15 “…Fastest way for ISS personnel to get info is to go to PD direct via e-mail, not the PDL”

2.16 “PDs constantly tracking data in PDL data assets to make sure it is up-to-date…When NASA personnel are not using the PDL…”

2.17 “For payloads that fly many times, it would be better to have information by payload then the particular info needed for an increment/flight could be pulled from this…”

2.18 “PDL appears to be utilized as a pre-mission tool & is not given great emphasis when dealing with real-time responses to issues…”

2.19 “Get a consensus of what data the PD should be inputting & where..”

Question 3. ISS Payload operations planning and execution practices enforce adherence to standards and programmatic requirements to unnecessary degree.

Comments

3.1 “The problem is not really adherence. The content of the standards and programmatic requirements are not focused on the needs of the investigators. The problem pervades the whole program”

3.2 “Scheduling training sessions are difficult & they are often not firm until a week before the date….makes planning trips difficult, raises airline travel fares”

3.3 “Direct interaction with the PI should occur much earlier”

3.4 “…and the standards are not easily traceable”

3.5 “…our experience has been that payloads consistently take a back seat to operational requirements… Payload XYZ would not have received its required run time had it not been for the crew working during their time off… Payload XYZ flying attitude detrimental to its science”

3.6 “Realtime ops-major problem is inability of program/cadre to understand and accept that most payloads are not on console 24-7 & not physically located within HOSC…NASA has supported idea of telescience but has not the practical implementation of it…no reliable mechanism for payloads to stay informed of events & decisions that occur while they are off console...applications &tools are not accessible to everyone...simple things like crew procedures & OCRs aren't accessible unless sitting on console...LIS reps do not view their function as the focal point for payload/cadre information flow...”

3.7 “Working with limited crew time/vehicle resources make this necessary…this is one of the major reasons for success achieved in early increments…”

3.8 “…for pre-flight operations planning this is true…support from POIC cadre for on-orbit testing has been excellent and accommodating”

3.9 “…process seems to require "simple to operate" experiments conform to integration processes that may be appropriate for complex, interactive experiments…system may not adequately support the needs of these complex research protocols…Perhaps one size does not fit all”

3.10 “This is especially difficult when IDD & reporting requirements are constantly changing…change the Payload ops philosophy that if a payload has been flown before it makes no difference…therefore it must be redesigned, rebuilt, etc….Treating the individual payloads with the same requirements as an ISS core or express rack facility should be reevaluated and eliminated...Have a simple set of interface requirements for payloads that were previously flown...”

3.11 “This is particularly true in the execution practices area….even the simplest changes to plans & procedures require full formal reviews & approval prior to implementation, normally at a cost of not getting the work accomplished until days later if at all...”

3.12 “I was unable to make the appropriate experimental changes to accommodate for the extreme delay in return of payload cell samples…from the station….allow the investigator greater access to absolute cut-off timelines for experiment protocol modification, based on flight scheduling delays, so that modifications in planning as well as programmatic issues could be more easily dealt with...”

3.13 “The pre-flight timeline efforts were ineffective and artificially constrained command and telemetry capabilities possibly due to a lack of understanding of ISS/Express performance, KU band availability, Ethernet communications performance limits, etc. AOS/LOS predictions were unreliable and AOS coverage was "ratty", requiring multiple re-requests for telemetry...this contributed to the ineffectiveness of the planning practices and required more of a real-time implementation”

3.14 “In our case, planning was worthless as we rarely knew when we would fly and there was zero opportunity for the technical people to be in Houston to support ops and troubleshoot when problems occurred. In addition, being unable to actually train the astronauts resulted in several problems that resulted in corrupted or useless data”

3.15 “Consolidate”

3.16 “ISS Planning & execution team are flexible & work situations on case-by-case basis…”

3.17 “Retrospectively, I would agree, however going into a mission I am not confident that I would say that all unused practices were unnecessary…”

3.18 “At times, the cadre will not ask the crew a question & the PD and cadre end up spending days & weeks on a task that a crewmember could answer in less than 5 minutes”

Question 4. ISS Payload operations planning and execution practices are overly formalized with multiple approval levels.

Comments

4.1 “The question posed requires the investigator to penetrate the NASA organizational system; it would be better to ask investigators questions in terms of the end results of NASA’s processes.”

4.2 “Compared with Shuttle/Mir the computer software design process and training approval process-differing standards at JSC & MSFC, competing committee structures, changing requirements-are more cumbersome & frustrating”

4.3 “Too many operators & too few PD's”

4.4 “Currently OCR must be submitted before discussions w/flight controller…discussion before submission would ease the process…multiple levels contribute to misinterpretation and deletion of valid requirements…”

4.5 “ISS should be used as a research lab…PDs should have access to people doing the work…crew should not be inaccessible…”

4.6 “…Payload XYZ scheduling process is getting smoother…understanding most requirements cannot be timelined until much closed to their operation, the OOS & long term planning tools provide a reasonable opportunity for success…this knowledge gained during early scheduling appears to be ignored by & the PIs/PDs go through the whole process again just prior to payload activation...my experience with execution practices is good so far...”

4.7 “I spent almost 2 years developing the ___ payload planning data set in the iURC…iURC & OOS did not originally have the flexibility to easily handle the fluid nature of actual operations…changes were very difficult to implement…significant improvements to OOS have been made...pre-flight planning is overly formalized and rigid, short-term and real-time re-planning that occurs daily is very flexible...POIC Cadre has worked very hard to accommodate operations changes requested by all payloads...”

4.8 “It’s not so much the number of approval levels as it is the number of POCs that we have to keep up with…”

4.9 “True, the way it is handled now it is endless chaos…Go back to the way payloads were handled for Spacelab, Shuttle Mid-deck & Spacehab. That system worked well….Get a team of experienced Payload developers & ISS program managers to review all current deliverables and complicated approvals with a mandate to cut 70 percent...eliminate endless telecons & practice sessions prior to required program reviews...”

4.10 “This is true in the case of timelining…the only thing about a timeline that can be relied on is that it will change…with each iteration things get worse as constraints are not met and things simply don't work…similar problems apply to preflight timelines involving training & baseline data collection. These changes constantly & the effect is devastating on the investigators...”

4.11 “Many operations practices are a hindrance to actually getting the work accomplished in a timely fashion and mean very precious crew time is wasted due to high overhead associated with planning and getting approval to execute the required work…”

4.12 “My impression here is probably yes, but even as a guest investigator, I was not made aware of all the levels of approval…”

4.13 “Expect and plan for less formal, real-time, self-regulating (such as internet/Ethernet) communications protocol…and provide separate channels as necessary for high bandwidth users to prevent conflicts with payloads that have low telemetry demands. (The purpose being to reduce/eliminate the need to timeline routine communications).”

4.14 “Thankfully, DoD STP took the brunt of this, but we still worked with their office to provide inputs.. We would seem to go round and round to the point that I was highly skeptical that we would ever fly Payload XYZ.”

4.15 “Why do MOD, SpaceHab, and ISS all have different requirements, guidelines, and formats for developing crew procedures? NASA should develop a standardized set of requirements and formats to follow so that crew procedures developed, and validate an experiment could be used on any vehicle. I understand ISS utilizes an electronic system where MOD and SpaceHab do not. Maybe MOD and SpaceHab should adopt the ISS system? The ISS delivery template should be relaxed to the stage the hardware flies on, and not the increment. Some of the requirements have no value added. Procedures go through too many hands and the PDs may not see the final product unless they ask. The process for submitting and revising procedures to the program is very complex.”

4.16 “…Processing OCRs in mid-flight is longer to approve because of # of people…”

4.17 “See comments to next question”

4.18 “When the PD submits an OCR via PIMS, the reviewers sometimes review & comment on the entire procedure instead of the documented changes.. The PD has to defend a position that has already been approved/decided upon…the process takes entirely too long, even when you give adequate lead time, some comments are submitted late...”

Question 5. Multiple changes in interpretation of requirements for developing ISS crew flight procedures increase researcher workload unnecessarily.

Comments

5.1 “The hardware I’ve been involved with is very simple and multiple changes have not been a problem. It has been a problem to get 5 minutes of crew time to do a task because the schedulers insist on treating it as a 30 min exercise”

5.2 “I agree many changes are occurring that require significant re-examination & rework by the PIs and hardware developers; I do not agree that the attention to the changes is unnecessary. Changes need to be reduced or stopped at higher levels of development”

5.3 “Compared with Shuttle/Mir the computer software design process and training approval process-differing standards at JSC & MSFC, competing committee structures, changing requirements-are more cumbersome & frustrating”

5.4 “Operation is a science is normally not known by the scientists & interpretation is not always obvious”

5.5 “Payload ops process & reviewing of procedures needs to be standardized….there were 5 reviews of Payload XYZ procedures…changes were due to differing standards”

5.6 “There seems to be too many people involved in the ‘paper work’ aspect of ISS ops…Direct contact between the science team & crew is too limited”

5.7 “This stems from the issue that we are verifying that switches throw 30 degrees (instead of 29 degrees)…the sheer number of verifications, the endless modifying becomes overwhelming…safety verifications should be the only requirements that are not grandfathered...”

5.8 “Strong requirements re payload procedures up front would save a lot of PI/PD frustration just prior to payload start-up…POIC personnel do not review procedures early enough to allow changes to be made in a careful & productive environment…lesson learned: develop procedures from start to finish & then break them into smaller groups...”

5.9 “The system should be revised to enhance the prospects for research & minimize the difficulty in accomplishing the stated goals of the research, changes to experimentation should be viewed, as much as possible, as a matter of course, not the end of the world”

5.10 “To date, our flight experiment has not flown on ISS, the process has worked very well for us.”

5.11 “…program (needs) to settle on the requirements & establish a consistent interpretation of procedure development requirements (then this problem goes away)…the crew procedure review process ____ underwent 2 years ago was very time consuming and difficult...a level of detail was required that made it difficult to get final approval...some of the detail turned out to be unnecessary - crew didn't need it...the review process during real-time ops has been much easier to work with...”

5.12 “Responsibility of detailed procedure formatting to the ISS specs was originally placed on developers. This function was later added by the PODF, but the budget ran out. Currently, we now do the initial development & formatting, MSFC does a final scrub”

5.13 “This is especially a waste of time & a large unnecessary cost…having to revise a two page crew payload procedure 76 times for ISS that was successfully used on STS-XX is ridiculous…eliminate MSFC training teams & allow payload developers to interface direct with crew training personnel & training sessions at JSC...Have a JSC flight crew procedures team work direct with the PD to develop crew procedures...Publish a standard reference document for PDs to develop crew procedures then don't change it for at least 24 months...Overall: eliminate MSFC/Boeing/TBE as the unnecessary middlemen in ISS payload processing...POIC should be eliminated...PDL should be a library finalized only within 60 days of flight...Revised and simplify the process for developing crew procedures”

5.14 “The entire procedure development & training process has far too many people involved…we submit procedures that work, have been seen by the crew & then are changed (butchered)…investigators are forced to dry run training sessions to avoid wasting crew time doubling the time to do a training session...trying to get a simple in-flight procedure was an exercise in idiocy with numerous procedure people changing our words without actually knowing what they were dealing with. Not a good experience”

5.15 “This is definitely true although it has been improving some. There is still inconsistency in interpretation based on the individual doing the evaluation of a product, but the range of inconsistency is narrowing…”

5.16 “I had no interaction with any issue relating to flight crew procedures…”

5.17 “ISS and STS procedures should be controlled in like manner. Commonality should allow the ISS program to use existing PD procedures from STS flown payloads in the development of procedures for ISS. The Payload Display Review panel & processes for crew procedures review is unnecessarily subjective even prior to crew involvement. The panels seem to make firm judgement calls on behalf of the crew that may not represent a hard crew preference. These panels can significantly and possibly unnecessarily impact PD development programs by these decisions.”

5.18 “Not only multiple changes in interpretations, but that fact that different members of the payload staff had differing opinions as to what the requirements really meant. Also being ‘crapped’ on because we did not meet a formatting requirement when no formal requirement existed (had not been approved) drove us nuts as we reformatted information that did not change just so a ‘bean counter’ could feel good about the fact that they had hassled an experimenter. Being naive, I assumed that people in the payload office would be more supportive and helpful instead of throwing up road block after road block doing their best to hinder any forward progress on our program. To be honest, it is my sincere hope that I never work another NASA manned space flight program. On a positive note, there were certain individuals that were absolutely fabulous in their support and enthusiasm. However, they were few and far between.”

5.19 “procedures regarding displays are hard to develop due to changes by the PDRP…procedures without displays are simpler to write..”

5.20 “Changes in interpretation of procedure requirements occur often and seem unnecessary…overall procedure seems too complex…goes through too many channels”

5.21 “Some requirements have no value-added. Procedures go through too many hands & the PD may not see the final product unless they ask…The process for submitting & revising procedures to the program is way too complex…”

5.22 “I am not sure how you can achieve (actual accountable) control without being formal. However, considering the latter ‘have too many approval levels’ I would respond…that…there are too many areas of responsibility that are affected by a single payload’s operations & each of these areas should have the opportunity to comment on a particular operating procedure. But then each are has its own approval hierarchy...so here I would encourage a reduction...rubber stamping is not necessarily value-added if there is not actual participation by that individual...”

Appendix D. Examples of Excessive ISS Requirements

Background

The POCAAS Study Team has been tasked with finding mechanisms to decrease the cost of payload operations on ISS. During the course of that study, it became apparent that some members of the team had been either principle investigators (PIs) or payload developers (PDs) on both Shuttle and on current payloads/experiments flying on ISS. Upon polling those PIs/PDs on the POCAAS team, it was found that there was complete agreement relative to the payload integration and payload operations on several points:

5. It takes more time, money and effort to fly an existing flight proven Shuttle payload on ISS as a re-flight payload than it costs to fly the same payload on the Shuttle. The factors among the PI's/PD's varied from a factor of 2.4 to 4.0.
6. One of the major cost drivers was in the excessive and repetitive documentation requirements imposed on ISS payloads, coupled with crew training, mission ops procedures, labeling of front panels and other items to be discussed in the body of this report.
7. The present requirements imposed on ISS payloads are excessively tighter than on Shuttle for no apparent reason.
8. The requirements drive the documentation and hence the cost.

The PIs and PDs on the POCAAS team believe that, if the requirements could be relaxed (both payload operations and payload integration) while maintaining all safety considerations, flying payloads on the ISS would be easier, quicker, and less expensive and the current massive and redundant documentation requirements would be significantly reduced.

The following requirements represent a compilation of ISS requirements from three real ISS payloads that were first flown on Shuttle missions and then either were modified to meet the new ISS requirements (e.g., rear air breathing) or were designed from the ground up for ISS. The inputs relative to the specific ISS payloads come from three veteran PIs and PDs. Larry Delucas, Al Sacco, and John Cassanto comprised the user team directly concerned with this requirement study. The technology categories encompass protein crystal growth, inorganic crystal growth, and microencapsulation of drugs and, therefore, cut across several technical disciplines and should be representative of the kinds of payloads and problems for new users planning to fly on ISS. This report details and recommends changes to various aspects of processing a payload on ISS based upon the experiences of the POCAAS user team.

The information to be presented utilizes a format which first defines the item to be discussed for example, mission ops/crew procedures, then the payload is defined, and the PI or PD identified. Then there is a discussion of the issue or problem encountered and sometimes a resolution is found, other times there is no resolution, resulting in time and money being wasted.

One final point, the POCAAS user team firmly believes that we have only scratched the surface of the top of the iceberg. We believe that an extensive study should be conducted consisting of more PIs and PDs in conjunction with the appropriate NASA personnel/contractors to take a fresh look at the existing ISS requirements with the goal of relaxing and/or eliminating *requirements so long as safety is not jeopardized. This would have the affect of reducing the cost, the time and the effort to fly a payload on ISS for the PI, the PD, and NASA.*

The following sections present actual case studies, which provide the rationale for reducing/relaxing payload operations requirements and payload integration requirements. The results are separated by payload operations examples and payload integration examples.

D.1. Payload Operations Examples

1. Item Description: Crew Procedures

Payload: MEPS

Principal Investigator: Dr. Dennis Morrison

Payload Developer: John M. Cassanto

Requirement: There will be a mission operations procedure document approved by NASA MSFC personnel.

Discussion: The crew procedure to operate the MEPS payload is a relatively simple procedure that is divided into several sections dealing with powering up, Process Control Module change out, and powering. On the STS-95 flight, John Glenn was trained to operate the hardware. The MEPS Shuttle hardware required some modifications to meet the ISS rear air breathing requirements for the UF-1 ISS mission as well as upgrading to a small computer integrated to the chassis, which made the system more compact. In addition the PCMs incorporated rear connectors that eliminated the crew from having to mate and de-mate cables for each PCM change out, which markedly reduced crew time. Figure D-1 shows the improved ISS configuration compared with the Shuttle configuration. Note that the cable from the NASA ECC computer has been eliminated and hence is one less task for the crew to mate and de-mate during a PCM change out. Funds had to be spent (for 8 months) to satisfy the crew procedure modifications imposed. We were required to make 77 revisions in 8 months. Ninety-five percent of the revisions were trivial; for example, add a space between the dashes in front of a number. The final procedure after 77 revisions in 8 months is not markedly different than the procedure that we started with from STS-95. An example of this is shown in Figure D-2, which shows the ISS PCM change out procedure. There are some extra steps in the Shuttle procedure relative to the cable, which obviously is not needed in the ISS procedure, but the procedures are essentially the same.

Recommendation. *Grandfather in procedures from previous flights (Shuttle, etc.). Allow the crew training document people to recluse themselves if the PI/PD and the crew agree at the first meeting. For new payloads, minimize the impact of the crew procedure group because it takes the PI/PD large sums of money and time to satisfy trivial requirements – see below.*

2. Item Description: Crew Procedures

Payload: CPCG

Principal Investigator: Dr. Larry Delucas

Discussion: Lack of commonality between ISS and SSP programs. UAB/CBSE flew the same malfunction and alternate procedures on both ISS and Shuttle. It is unbelievable how different they were. ISS does not recognize the SSP-formatted procedure, and vice versa. We have been flying these same procedures on Shuttle for several years, but ISS still required us to support and perform "usability certification."

Recommendation. *Grandfather in SSP payloads to fly with their existing documentation or make the ISS and SSP formats the same where applicable. Why are we reinventing the wheel?*

Discussion: Delivery dates for experiment procedures are unrealistic and jeopardize successful experiment operations. Having to submit final procedures for a re-flight experiment 7 months prior to the start of an Increment results in a costly change process.

Recommendation*: Seven months prior to the start of an increment is fine for new experiment systems but the program should have a more realistic time requirement for re-flight experiment procedures such as 3 or 4 months prior to the start of an increment.*

Discussion: There is no clear process or configuration control of experiment procedures once they are onboard.

Recommendation*: Institute a clear process for configuration control of experiment procedures onboard.*

Discussion: The Op Nom processes as well as other procedure ECR/TCM reviews are very slow.

Recommendation*: Delete some of the mandatory reviewers or tell them to pick up the pace.*

3. Item Description: Procedure Training Certification

Payload: MEPS

Principal Investigator: Dr. Dennis Morrison

Payload Developer: Mr. John M. Cassanto

Requirement: All ISS Payloads payload crew trainers will attend a course given by the MSFC to ensure that the PD/PI will train the crew in the proper manner.

Discussion: Numerous cases exist in which PIs/PDs have flown multiple missions (three or more) on the Shuttle that are re-flying similar or upgraded hardware on ISS. The PI/PD personnel that have trained Shuttle crews to operate the specific payloads are experienced and veterans of space flight operations. There is an ISS requirement that essentially states that before any person can train the crew, that person must take a course to be certified to train the payload specialist. Again, this is a waste of time and money for those PIs/PDs who have flown multiple missions. The requirement needs to be eliminated for veteran payload PIs and PDs.

Recommendation: *Eliminate this requirement for all payloads that have previously flown and trained crews (the veterans).*

4. Item Description: Payload Operations Data File and Payload Display Review

Payload: CPCG

Principal Investigator: Larry Delucas

The PODF-PDRP Payload Authorization Process states the following: "Before ISS crew operated payload equipment can be flown, the developer is required to acquire an authorization letter from the Payload Display Review Panel (PDRP) chairperson at Marshall Space Flight Center (MSFC). The authorization letter will testify to the payload's 'operability' by on-board crewmembers and grant the use of panel-reviewed procedures and displays for crew training and subsequent flight."

Discussion: The PODF-PDRP was established at MSFC to provide assistance and guidance to PDs in acquiring an authorization letter. Working together as a team that includes both the PD and Houston's Astronaut Office, the PODF-PDRP is committed to helping produce "usable" payload displays and procedures that facilitate the crew's role in obtaining anticipated on-orbit scientific results. This pamphlet will acquaint the PD with an overview of NASA's process for securing payload training and flight authorization and the role the PODF-PDRP plays in the process.

The authorization process is a disciplined process whereby a PD's displays and procedures are verified against ISS standards. They are also validated for operability via the successful completion of a "usability" evaluation that exercises the procedures and displays. The process is iterative as well as interactive, consisting of a series of display/procedure design and review activities. The authorization process identifies the following tasks as germane to the delivery of flight-ready displays and crew procedures:

- The PD develops displays and procedures per approved standards with PODF-PDRP help if requested.

  ***Recommendation**: This function should stop with display and procedures standards. Payload developers should be able to follow the standard without a NASA tutorial service.*

- PD validated displays and procedures are submitted to the PODF-PDRP for review.

  ***Recommendation**: The review process is a long and expensive luxury. This process can take months while the review panel twiddles with minutiae. Eliminate this function. If the crew cannot operate the display or application because it is unusable, then it will only hurt the PD. Therefore, the PD is motivated to follow the standard to a reasonable degree.*

- A Mini-Team appointed by the PODF-PDRP reviews the displays and procedures for standards compliance and operation issues, and then identifies any discrepancies.

  ***Recommendation**: Ditto, same as above.*

- The PD addresses the discrepancies (if any) and provides resolution.

  ***Recommendation**: Allow the PD to determine discrepancies on his/her own and correct as is reasonable.*

- A "usability" evaluation is planned, scheduled, and conducted by the Mini-Team with crew office personnel.

  ***Recommendation**: Unnecessary. Crew will have a chance to work with the display or procedure during training and any minor problems could be corrected subsequent to initial crew exposure.*

- Any impediments uncovered during the "usability" evaluation are reported to and corrected by the PD. The PDRP will help the PD in the correction activity if requested.

  ***Recommendation**: Allow the PD to self-correct. There is no need for a display police.*

- A PDRP panel then convenes and issues an authorization letter for crew training and flight.

  Recommendation: *Eliminate!* ***Further Comments***: *Because the PDRP function would in essence be eliminated and replaced by a single individual who would be responsible for publishing and maintaining a standard, most costs associated with this body would also be eliminated such as*
  ** Maintaining a PODF/PDRP web site*
  ** PDRP Training Classes*
  ** Software costs for DUET and associated maintenance and personnel*
  ** Data storage costs for PD Displays that are kept on file*

Recommendation: *Greatly modify (downsize to eliminate) the MSFC Payload Authorization Process. This would save time, money, and excessive documentation and grief for the PI/PD. It would also speed up the process of getting a payload on board and save NASA money.*

5. Item Description: Payload Data Base Requirements

Payload: ZCG-FU

Principal Investigator: Al Sacco

Requirement: All ISS payload data will be submitted to the PDL.

Discussion: A lot of effort (manpower/time) gets put in for updating data into PDL. But the people who need the data don't seem to use PDL effectively. They would rather contact the PD for data. Specific example: During ZCG-FU turnover at KSC prior to UF-1, the stowage people had a hardware drawing and part number dating back to 1998 while the updated version (dated 1999) was in PDL. We had to e-mail the correct drawing again. There are a lot of redundant data in various data sets in PDL.

Recommendation: *If we are going to have a PDL, make it easier for other NASA groups and NASA contractors to obtain the data. Also mandate that all requests for payload information be obtained from the PDL. The PI/PD should be contacted only as a last resort.*

Additional PDL Considerations. PDL inputs and updates are difficult to manage. Spreadsheet information forms filled out and submitted would be easier to work for the PDs and could be setup to be transferred to the larger PDL database. There is a strong need to reduce the effort and time in supplying and updating information. With the current system, the flow down to other compiled documents is slow, causes confusion, and leads to outdated information being worked and reviewed.

6. Item Description: PODF (Payload Operations Data File)

Payload: ZCG-FU

Principal Investigator: Al Sacco

Discussion. Crew procedure standards kept changing; it's like a moving target. Procedures conforming to standards get change requests from different ISS increment crews (Example: Cases with checkmark and/or verify use, one crew member was not comfortable with the meaning of checkmark which suggests an action.)

Recommendation*: Go to guide lines while maintaining all safety considerations. Consider crew inputs, but then use common sense and explain why what the PI/PD has designed is okay and will work.*

7. Item Description: Two Centers Doing Very Similar Jobs Requirement

Payload: All

Principal Investigator: All

Discussion: There are overlaps and some conflicts between crew training teams at two centers: MSFC and JSC. One team would be sufficient. Overlaps in multiple team reviews occurs doing evaluations of labels for crew training purposes. The same topics like Payload labels are reviewed by the Marshal - PDRP = (Payload Displays Review Panel) and the IPLAT (labels team) at JSC where additional or conflicting labels requirements may surface. There is no need for two teams to be involved for this function.

Recommendation: *Pick one center to do the job. Crew training clearly should be performed at JSC because they are the most experienced.*

8. Item Description: Multiple Inputs of the Same Data

Payload: CPCG

Principal Investigator: Larry Delucas

There are many examples of the identical information being provided to different places/groups within NASA or to contractors working for NASA. Again, this defeats the purpose of making ISS easy to access and drives up the cost of flying on ISS for the PI, the PD, for both NASA-funded experiments and private sector commercially funded experiments. It is also discouraging, and it is easy to see commercial entities walking away from the microgravity opportunities on ISS.

Discussion: Within PDL we are required to input data into the EIA for each payload for each increment and for each flight.

Recommendation*: Have a Payload EIA that is not increment/flight specific.*

We also are required to input data for the ICDs and PVPs for each payload for each increment, and for each flight.

Recommendation*: Have a payload ICD and PVP that is not increment/flight-specific.*

The Manifest/Planning Groups call or e-mail PDs asking for the same information that is in the EIA. They do not look at the EIA probably because the report from PDL is not the easiest format to follow. This information will be placed into Increment Annex 5 tables of the IDRD.

No clear direction as to where data is really supposed to be input to the program. One day, PDs are asked to input ISS video requirements into PDL, then they are told to e-mail it to this person, and then they are told put the Shuttle video requirements into PDL. When PDs pointed out that the ISS requirements are no longer in PDL the Shuttle people did not know this.

COFR inputs require PDs to status items that are already being tracked by the EPIMs, but it does not matter if someone at JSC wants to see this on the COFR inputs so PDs must resubmit this.

PDs input data into PDL, iURC, OPMS, PIMS.

Recommendation: *Let's agree to have a primary NASA and/or NASA contractor point of contact for all inputs to ease the burden on the PI/PD.*

9. Item Description: Verification

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: Too many requirements have no value. As an example, originally, human factors criteria were "design to" guidelines that PDs referenced during payload development. Now they are strict requirements that must be verified by the PD teams, checked by crew office representatives, yet ignored, or disregarded because of added burden on the flight crew.

Recommendation: *Most PD teams know what requirements have little or no value and are ultimately ignored after a great deal of manpower has been expended trying to meet and verify these requirements. UAB/CBSE thinks that a requirements review including the program, RPOs, and PDs should be done to get these requirements out of the program. Other examples include specularity, acoustics, etc.*

Discussion: EXPRESS Rack Verification Data deliverables are tailored to the EXPRESS Office organizational structure and not the EXPRESS Rack Interface Definition Document in which payload interface control is documented. This results in applicability confusion during the submittal and review process.

Recommendation: *Shuttle and SpaceHab all require verification data submittals based on ICD requirement number and not discipline numbering systems. EXPRESS Rack should do the same.*

Discussion: There is a lack of coordination of teams regarding PTCS/FCU testing. The PTCS/FCU pre-test coordination communication between MSFC, the PD team, and KSC regarding testing, the required versions of databases, and availability of other support software such as EHS have been issues. PDs would like to have this process better defined and streamlined to include more communication prior to on-dock at KSC. PDs would also like to point out the necessity for testing between the PD Remote Site and MSFC prior to on-dock at KSC to work out commanding/telemetry issues prior to testing.

Recommendation: *Name a NASA lead to handle this coordination. Develop and document a well-defined and streamlined process to include more communication prior to on-dock at KSC. Provide a way to test between the PD remote site and MSFC prior to on-dock at KSC to work out commanding/telemetry issues prior to testing. Make the flight commanding, telemetry, and EHS versions available and in sync with the KSC PTCS testing schedule.*

Discussion: MSFC RPI testing prior to KSC PTCS. There is an important need to perform remote payload interface (RPI) testing with MSFC prior to PTCS testing at KSC. PDs have spoken with MSFC and they stated the main concern that prevents PDs from testing prior to PTCS on the test string is the ability to have the approximate Command and Telemetry databases for our particular flight made available at MSFC some weeks prior to PTCS testing as well as having MSFC resources and personnel available for this type of test. This can often be a cost and schedule impact to PDs and NASA KSC support personnel if these are not made available.

Recommendation: *Provide the direction and funding to bring this type of testing in sync with the KSC PTCS schedules.*

Discussion: The ScS was not designed to be a verification tool that it is now trying to be. This is an incomplete verification test bed for subrack payloads.

Recommendation: *Implement the following nine items (see Suitcase Simulator below) and convert one of the MSFC EXPRESS racks into a tester that can connect into the HOSC for commanding/telemetry/H-S processing so PDs can checkout their payload interfaces prior to going to KSC.*

10. Item Description: Suitcase Simulator

Payload: CPCG

Principal Investigator: Larry Delucas

Item 1: The Suitcase Simulator TReK interface capability needs to be enhanced. Testing (or attempts to test) using the ScS has identified some shortcomings that prevent some significant portions of the payload communicating with its ground systems. The ScS will not pass a health and status packet received from a payload to the TReK interface for processing by the ground systems. This prevents the PD from performing tests that fully exercise the experiment to ground system data flows. A workaround exists that would let the experiment code "fool" the ScS into passing the data on through. This is considered an ill-advised approach because it requires modification of the experiment and ground system software that is ostensibly being tested. Conversations with the ScS Help Desk indicate that a change is being processed to rectify this problem and that the change paper is awaiting approval.

Item 2: The ScS TReK interface is limited to passing data for only one APID for telemetry. Per the EXPRESS IDD interface, a single payload can configure up to six APIDs for telemetry. Further, the ScS otherwise supports the operation of two payloads simultaneously, meaning that if data was being sent over multiple APIDs for telemetry, only data from one of the APIDs from one of the payloads would be available. Payloads that utilize multiple connections (e.g., one for the experiment processor and one for a thermal carrier) cannot adequately exercise the operating configuration of the payload with its ground systems given this constraint of the ScS.

Item 3: Include flight cables that match the flight hardware from a payload perspective as part of the ScS. This shall include the ER front panel data/power connections as well as the ISIS drawer data/power connections.

Item 4: Provide certification of the ScS for connection to flight hardware.

Item 5: Add capability for commanding from a PD's ground system via ScS to a payload.

Item 6: Add a report generation capability. So the PD could utilize this as part of their verification package documentation.

Item 7: Enhance the data display capability to make it easier for users to see a payload H/S as well as telemetry data in something other than HEX values. This would include a real-time data delog capability.

Item 8: Enhance the archival of a payload's H/S and telemetry data so that this might more easily be moved to another platform.

Item 9: Enhance/simplify the user guide.

11. Item Description: Training

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: The ISS program requires payload simulators be delivered to JSC. This can be very costly in development of high-fidelity equipment that may be utilized for a few hours during crew payload training.

***Recommendation**: It's less costly for a project to maintain a qualification unit, as a training device, for internal use and ship it to the training facility when needed.*

Discussion: Payload training is very limited and performed too far in advance of flight. Therefore, hardware must be developed/readied well in advance, which results in added cost to the project. The other risk is payloads could complete hardware development after training and jeopardize experiment success because of crew unfamiliarity.

***Recommendation**: Properly integrate training requirements into the development schedule of the experiment payload on a case-by-case basis based on factors such as complexity, whether the experiment has flown before, etc.*

12. Item Description: Operations and Integration Process

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: NASA Data Review: there is a lag between PD's data submittal and receiving comments. Everyone wants data and now, but when you give it to them, they only check off a box.

***Recommendation:** Relook at the template dates and only ask for data in a time frame that NASA can provide the appropriate personnel to review this information.*

Discussion: The label process/requirements keep changing.

***Recommendation:** Get the crew office, the human factors people, the decal lab, and some PDs together and define something we can live with and grandfather the current payloads.*

Discussion: At MSFC, there are various configurations of machines, which make up requirements to perform testing or support a simulation or COFR or flight. These machines and their configurations are constantly in a state of flux due to limited funding and resources. The fact that they are in a constant state of flux causes a PD to deal with several problems in testing, simulation support, and COFR. UAB/CBSE and other PDs often are left in a state of catching the misconfigurations and reporting them, then waiting for them to be resolved, before continuing with their work. This, at times, can take extraordinary amounts of time. At times, it can prevent a PD from receiving data during a simulation, and it also prevents them from being able to use applications such as PIMS and MPV during a simulation. Usually, it takes hours to days to get a problem fixed. These problems shouldn't be there to start with, but because they are constantly reconfiguring due to lack of resources these problems appear.

Recommendation: *Properly fund MSFC to configure the systems at MSFC to support the activities for flight and pre-flight. If not, distribute the documented availability of EHS versions for flights and which capabilities they will include. Also, if it is determined that some of these capabilities will not meet the documented EHS versions, then immediately distribute these shortfalls to the PDs.*

Discussion: C&DH telemetry database out of phase with PD's verification needs. The availability of the C&DH telemetry database, which is utilized by the TREK in the verification/checkout process, is out of sync with the needs of PDs.

Recommendation: *PDs would like to request that this process be reevaluated based upon the end-users' needs. As it stands today, this database must be created by hand, which is very labor intensive.*

Discussion: It is difficult to determine where the current SODF and PODF procedures are available, thus, some old ones were used to build simulation/training libraries.

Recommendation: *Institute a clear process for configuration control of experiment procedures onboard and on the ground.*

D.2. Payload Integration Examples

1. Item Description: Electrical Bonding of Payload Structures (Verification Number EL-ER-022). – Requirements from SSP-PVP-ERP, Issue A (3-22-00)

Payload: MEPS

Principal Investigator: Dennis Morrison

Payload Developer: John M. Cassanto

Discussion: The basic bonding requirement makes sense and must and should be performed for any payload or spacecraft. The requirement is to ***verify by test, analysis, and inspection*** (see Figure D-3) that the bonding is as per the requirement. Then a Certificate of Conformance (C of C) and a Verification Inspection Report must be generated and signed off (two separate documents). It would seem prudent to combine these since the C of C is inclusive and states "I hereby certify compliance with the verification requirements as specified in the SSP 52000-PVP-ERP, Issue A". Most payload engineers will not have a problem with this requirement since it is recognized as needed, but only one document (these are one pagers) is really necessary, not two.

In addition, since the payload (MEPS) will be in orbit continuously for more than one increment, we were informed by one of the MSFC contractors that we would have to fill out the paper work (the same C of C) again for the next increment (see Figure D-3). In the first place, my integration person cannot run a bonding test on hardware already onboard ISS. In the second place, if I signed another C of C (which I would not do) stating that the bonding had been tested, analyzed, and inspected, I would be signing up to something that was not true for the date of the second increment. The MSFC contractor thought that it might be possible to write a letter explaining that the hardware had been tested, analyzed, and inspected for the first increment, and would be valid for the next increment. Yes, the payload developer or user could do that, but ***why not change the requirement to take into account that many payloads will fly more than one increment and***

eliminate the user having do duplicate, unnecessary paper work to have someone at the POIC fill out a square.

Recommendation*: This requirement should be modified to eliminate problems associated with a payload staying in orbit for more than one increment. Make the requirement nonincrement-specific.*

2. Item Description: ISS Payload Label Approval Team (IPLAT) Requirements

Payload: MEPS

Principal Investigator: Dennis Morrison

Payload Developer: John M. Cassanto

Discussion (a) Switch Plate Lines boxed – Square or Round Corners: The MEPS I hardware that flew on Shuttle Mission STS-95 was slightly modified for flight on ISS. The main difference being that all ISS payloads must incorporate "rear air" breathing as opposed to Shuttle requirements, which allowed front air breathing. In addition, several other improvements were made to reduce crew time and to make the unit more compact such that the logistics of sample transfer could be made simpler and more efficient. In the process of performing the various tests to accommodate the C of Cs, we ran into a problem with the new nameplate for MEPS. We added additional capability to the front panel, and the requirements states that the switches will be outlined by a visible line to group the switches. On the face of it, this is a realistic rational requirement. The requirement also goes on to state that the enclosure (the corners) for the switched lines can be either squared off or rounded. This payload developer made the decision to square the corners. We were required to submit a drawing of the front plate, which showed of course that we had squared off the corners of the lines grouping the switches. We received a letter back, which said we were "out of spec" and that we had to redo the front plate of the hardware with rounded corners. Since this request was not worthy of an engineer's time, we wrote a letter explaining that the request would not be honored because the requirement clearly states that either option squared or rounded corners was acceptable, and it was a waste of time and money. It did, however, take time and money to document the case that we would not comply. Figure D-4 shows the switch plate that caused time and money to be wasted because of the IPLAT decree. Figure D-5 shows the alleged IPLAT label violation, but also shows the ISS requirement, which is at variance with the IPLAT decree.

Recommendation: *Greatly reduce the authority of IPLAT. Mandate that the IPLAT people who interpret the requirement fully understand the ramifications of their direction, which is sometimes at variance with the requirement. Eliminate the interpretation of the IPLAT to change the requirements. No one cares if the ink lettering around a switch grouping is squared off or has rounded corners. Also, let's use some common sense so we don't waste the time of the PI, the Payload Developer, and the program manager because the program manager and the integration engineer have to send emails and letters to the IPLAT. We do not need a label police. This is clearly a case of time and money being wasted.*

Discussion (b) Arrow pointing to High Voltage Power Supply: The MEPS flight hardware has a high voltage power supply that is controlled by a toggle switch on the front panel. At crew training, it was requested by the crew that we utilize an arrow to identify the LED which indicates power on. Figure D-6 shows the switch with the arrow. IPLAT requested removal of the arrow (see Figure D-6a) because it implied that the switch rotated, even though it is clearly a toggle switch as shown in the photograph.

***Recommendation**: Let's get IPLAT and the crew on the same page so that needless emails and letters are not needed to resolve non-issues. The IPLAT request is understandable; however, the crew will operate the payload, and if the crew and the PI/PD are comfortable with the switch functions, there is joy.*

Discussion (c) Add arrow on standard videotape for direction of insertion: The MEPS flight hardware utilizes a standard COTS video recorder that has been ruggedized to record the formation of microcapsules. It therefore utilizes standard videocassette tapes that need to be changed out periodically. IPLAT requested that the videotape cassettes be modified with an arrow for direction of insertion as shown in Figure D-7. Both the PI and the PD believe that the crew are intelligent and have sufficient background and training to insert the standard tape cassette properly without having to add an arrow for direction of insertion.

***Recommendation**: We do not need to overcomplicate simple procedures. Video recorders are standard, and there is no need to modify COTS cassette tapes with insertion instructions for the crew.*

Discussion (d) Go, No-Go vs. Ready/Not Ready LEDs: The MEPS flight hardware contains two LEDs (see Figure D-8), which indicate that the experiment can be conducted or cannot be conducted and state Go, No-Go. IPLAT recommended that this be changed to Ready/Not Ready (see Figure D-8a). The crew did not object to the Go, No-Go nomenclature, and it would be costly to change the silk-screened controller panel. In addition, the wording Ready/Not Ready would not fit on the panel. Accordingly, we are flying with the Go, No-Go nomenclature. Again, wasted time and money.

***Recommendation:** We need to rely more on the crew and their inputs. If at crew training, the crew is happy with the labeling, and the PI/PD is confident that the crew understands the hardware and is comfortable with it, it is not clear why IPLAT is needed for this specific example.*

3. Item Description: Payload Color Front Plate Requirement

Payload: MEPS

Principal Investigator: Dennis Morrison

Payload Developer: John M. Cassanto

"Payloads shall select interior colors in accordance with the requirement of SSP 5000-IDD-ERP, Table 12-1. (12.5.1)".

Discussion: The MEPS Shuttle payload with modifications was going through the payload integration cycle to be reflown on ISS. The hardware is basically the same with the exception of the addition of rear air breathing (ISS requirement) and minor changes that reduced crew time. The PI/PD was told that the color of the unit, blue, (on the front end and faceplate) was wrong and had to be off-white. Please see Figure D-9 for the ISS color requirement (section 12.5.1 of SSP 52000-IDD-ERP Issue B dated 12/13/00). After many discussions and emails/letters the PD decided that the prudent thing to do was to ignore the requirement and document the decision with a letter. The payload will fly as the same color it was on Shuttle. Again, time and money was wasted. *One could make an argument for a standard color for new ISS payloads being developed from the ground up, but it is not obvious why there has to be a spec on the payload color. There is no color spec on Shuttle payloads.*

Recommendation: *Eliminate this requirement for existing Shuttle payloads that will fly on ISS. Let's get some common sense back into space experiments. No one should care what color the payload or the front panel is so long as it passes all of the required tests (outgassing, EMI, vibration, acoustics etc), and the massive amount of integration paper work is provided, and has approval from the JSC safety board to fly.*

4. Item Description: Microgravity Testing of the ZCG-FU hardware

Payload: ZCG-FU

Principal Investigator: Al Sacco

Discussion: An exorbitant amount of time and money was put into accomplishing these tests that could have been saved for others activities. The tests cost in the neighborhood of $20,000 to perform not including all the ancillary costs to support it by NASA and payload personnel.

Recommendation: *A simple evaluation of the hardware would have shown that its microgravity impact was insignificant compared to the requirement.*

5. Item Description: Acoustics Verification

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: UAB engineers went to great lengths to make a set of flight incubators as quiet as possible and then we performed a preliminary test in our acoustics chamber at UAB. An engineer observing the test noted that we were exceeding the ISS allowable acoustics levels. We then informed him that we had not yet turned the unit on. It turns out that the air passing through our acoustic chamber's baffels on the top of our anechoic chamber were making more noise than the ISS requirement allows. When we finally turned our incubator on, it too, was exceeding the ISS requirements. We then used a great deal of time and money designing a muffler to cover the air vent (this is the only item that produces any sound from the unit).

For acoustic testing, it is required that the background noise levels be at least 20dB below the readings on the unit. So if the hardware produces a 40db noise level at 500Hz, the ambient noise level of the test facility should be 20db or below at 500 Hz. Thus, for ISS ER requirements, we must have an anechoic chamber that does not produce background noise levels more than 12 to 18 db for several frequencies. The anechoic chambers we have historically used (UAB's test chambers at the Spain Hearing and Speech Clinic) are unable meet this specification, so we tested our experiments at a MSFC Facility.

During an ISS training session we demonstrated the unit to several ISS program representatives and crew representative. Their first comment was to turn the unit on so they could get a perspective of the noise issue. As it turned out, the unit was already up and running. This demonstration was performed in a crew classroom (conference room) with only UAB and ISS personnel present. It was absolutely impossible to make the unit any more quiet, so eventually we were forced to get a waiver, after many months and a lot of money were expended to meet a ridiculous requirement.

In summary the program is mandating unrealistic requirements on small payloads built for Shuttle when the real noise producers are the vehicle systems and subsystems. We have received numerous feedback comments from Shuttle crews that have stated “it is impossible to hear these units against the background noise of the vehicle”. So why are we spending big bucks imposing unnecessary/unrealistic requirements on the experiments.

Recommendation*: The acoustic limits are too low, probably unrealistic. There seems to be more background noise on ISS than payload related noise. Modify payload acoustics limits (raise them) using ex-payload specialists as a sanity check to obtain a realistic value rather than an artificial number. If astronauts would wear earplugs (with microphones in them) or headphones, we could substantially relax the acoustics requirement and save a tremendous amount of money and time for every payload being developed for the ISS. An astronaut wearing an earplug or headphone for the 3-month increment is no different than wearing glasses for the same time period!*

6. Item Description: Ground and Flight Safety Data Packages

Payload: ZCG-FU

Principal Investigator: Al Sacco

Discussion: Ground and flight safety data packages should be combined and reviewed together. Much of the information is the same in both packages. This way we could go through one cycle of review and response.

Recommendation*: Change the format to combine the inputs utilizing typical PIs/PDs that have been through the system in conjunction with the ground and flight safety data package people.*

7. Item Description: Toggle Switch Angular Throw Requirement

Payload: ZCG-FU

Principal Investigator: Al Sacco

Section 12.6 (Verification Number HF-ER-020) of SSP 52000-PV-ERP, Issue A, dated 3/22/00 toggle switch displacement requirements.

Discussion: The toggle switch exception PIRN to satisfy the HF-ER-020 requirement (see Figure D-10) took 6 months to process to satisfy the fact that the ZCG circuit breaker displacement is 30 degrees versus the 22-degree requirement. This requirement should have been met by crew approval in training on our hardware.

Recommendation*: Eliminate the formal requirement, modify it to be a guideline, and use crew approval in training on the hardware to meet the guideline. Put common sense consistent with safety requirements back into conducting space flight experiments.*

8. Item Description: Express Rack Verification

Payload: ZCG-FU

Principal Investigator: Al Sacco

Discussion: Express integration teams at times take too long to evaluate the submitted verification data.
Recommendation: Speed up the process on the MSFC side.

9. Item Description: Drawing Requirements/Comments

Payload: MEPS

Principal Investigator: Dennis Morrison

Payload Developer: John M. Cassanto

9(a) A drawing will be generated for every item on board ISS.

Discussion: (1) The MEPS payload incorporates a commercial ruggedized video recorder that uses a standard videotape. We were required to provide an engineering drawing of a standard videotape cassette that can be purchased from K-Mart or Target that is utilized by most of the inhabitants of the civilized world. It should be noted that these tapes are included in a flight pouch, which also has a drawing. Clearly, the flight pouch drawing with dimensions that the tapes go into is needed, but it is a waste of time and money to draw a tape cassette. The drawing has to be generated, by a draftsman, then reviewed by an engineer, then checked, and finally signed off by the program manager. Again, time and money has been wasted. Figure D-11 shows the signed off drawing of the videotape cassette. If we are to document everything on ISS, there is an easier way. ***Why not take a digital photo? It serves the same purpose and saves time and money.***

(2) The MEPS payload incorporates a standard PCMCIA card that is standard on all computers today. Several cards also fly in a stowage pouch. Figure D-12 shows the signed off drawing for the PCMCIA card. Same argument as above.

Recommendation*: Revisit this requirement and eliminate those items that don't make sense and waste time and money.*

9(b) Several groups ask for drawings.

All investigators and developers on the POCAAS team.

Most of the time the drawings are in PDL, but the requesters do not have access or do not wish to take the time to retrieve these. We have to supply drawings to IPLAT, rack integrators, KSC PTCS integration team, and stowage to name a few.

- Data that was input and placed into a final format is not being carried over and used by the next increment/flight team. These include KSC TAPs, SODF procedures. This is getting better and the problems partially are because these processes start earlier that the previous flight data items being baselined. It would be better to have the process start later and have correct information/data items the first time through.

- Procedures:
  - Too many NASA people touching drawings
  - No clear actively used process (not consistent from increment to increment) Process in interpreted differently by different personnel
  - Procedure people look at wrong procedures because of the unclear process
  - PDs do not know where to input data. (OPMS-Which wing or is it PIMS)
  - The procedure input process starts too early and the training procedures are never the correct latest PD procedures. If a payload was previously flown, then the procedures should be in PIMS, but a PD cannot OCR changes to these until around launch-3 months, which is too late for the training.
  - Changes for some reason do not fully get implemented into SODF and PODF procedures and PD has to continuously check these for correctness.

Recommendation: *Review with PIs/PDs to eliminate the onerous drawing requirements.*

D-3. Miscellaneous

Management Issues

Payload: CPCG

Principal Investigator: Larry DeLucas

a) Item Description: Research and experiment success not emphasized or properly prioritized within the ISS program.

Recommendation*: Mandate a new program directive to support science or give science an advocate within the program at the highest levels.*

b) Item Description: The ISS payload program has far too many different organizations each with its own support staff. It is all but impossible for a small PI/PD team to effectively interface with an organization of this size.

Recommendation*: Ideally, the Research Program Office should be solely responsible as the interface between the PD and ISS, or the RPO should delegate all technical authority to the PD for working directly with ISS, EXPRESS, etc.*

c) Item Description: Invoking the Program Requirements on Payloads (PRP) document is too stringent, and not cost effective.

Recommendation: *The PRP is more suited as a guide that a NASA manager in the appropriate RPO could use to manage risk in selecting requirements consistent with the complexity of the payload and the experience of the PD.*

2. Development Issues

Payload: CPCG

Principal Investigator: Larry Delucas

a) Item Description: Research and experiment success not emphasized or properly prioritized within the ISS program. Level of effort required by PD teams to review and comment to PIRNs, CRs, facility documentation, unbaselined documents, coordination copies, draft issues, initial release, and white papers is excessive. Yet the ISS and/or facility program have mandated no technical support to payload developers in experiment design/development. ***The mass of paper created and required by the ISS program is staggering.***

Recommendation: *Minimize requirement changes. Go through an intense requirements review process to revise only what really needs to be changed. Stop the new CR/PIRNs daily changes out every other day business. Deal with individual situations as they occur, keep a running list and then update the documents every year. Only process real value-added requirements.*

a) Item Description: As stated in the management section above, documents like the newly released ISS Program Requirements for Payloads (PRP) document threaten the ability to cost-effectively develop new hardware. As it is presently written, the PRP is a serious cost impact to all existing hardware and will seriously impact the way costing of future hardware is accomplished. In some cases, it may be more cost effective to scrap a system in development as opposed to upgrading to the new requirements. General examples of new requirements imposed by the PRP include a menagerie of new planning documents, a stringent Mil-Std approach to parts selection, complex and costly reliability analyses, etc., that may limit ISS payload development to major aerospace organizations. We believe that even if the PD did complete all of the necessary documentation required by the PRP, NASA is not adequately staffed to review it. As a general rule, the CBSE has found that the impacts from this document approximately double the cost of payload development. The PRP effectively removes the ability of a project to make its own cost versus performance trades. CBSE has flown 37 successful missions without these "reliability at any expense" types of requirements. Safety concerns aside, can we afford "a highest reliability at any expense approach" in this budget environment? Although "better, faster, cheaper" may become a politically incorrect phrase to use after recent troubles with the Mars probes, swinging the pendulum back to the other extreme is not felt to be in the best interest of the program, either. These facts were brought to the attention of PRP authors on several occasions, but the response was the PRP has been baselined and the PD must comply.

Recommendation: *The PRP is more suited as a guide that a NASA manager in the appropriate RPO could use to manage risk in selecting requirements consistent with the complexity of the payload and the experience of the PD.*

b) There is a lack of clear integration process for payload developers. The amount of ISS documentation is excessive and is spread out over a vast number of different organizations. Several years ago, an ISS Engineering Study Team chaired by the current ISS payload program manager identified this issue as one of their primary findings in the final report. To date, a detailed user handbook still does not exist.

Recommendation: *Develop a meaningful user handbook that can be used by the PD as a guide through the process.*

D.4. Documentation

1. Item Description: Experiment Requirements Input – PDL

Payload: CPCG

Principal Investigator: Larry Delucas

The ISS program is utilizing electronic databases for a wide range of data input. The existing PDL system is not as straightforward as expected. There are concerns that this system has become so large and complex that it is a hindrance to streamlined payload integration. In our experience, the PDL has become increasingly costly to the program and is not user-friendly. It should be observed that this system is also not linked with other systems in the ISS Program that require the exact same data from the PD. Also, the method of configuration management of the data content in the PDL is unclear. This issue can result in inconsistencies in the data content and errors in its use. There should be a method for payload developers to work off-line within their organization to complete this information more accurately on an organizational team level. The system is designed for one person on one computer inputting data. Ultimately, the PDs lack configuration control of this information once it promoted to the ISS organizational level. In our opinion, the PDL system, although a good concept for reduction of paper and centralization of data, is more tailored to the ISS integration program process than a useful tool for PDs.

Recommendation: *The ideal solution would be a data library function that can be maintained on the PD's machine with inputs/updates being periodically uploaded to the PDL or database system when necessary. Also, most of these systems (PDL, URC, etc.) are tailored to the ISS program requirements and, at present, not optimized for the PD or any ISS user. Finally, in addition to the input process being labor intensive, the PDL does not allow for simple transfer of information from one payload or flight to the next (i.e. re-flights, similar experiment systems, etc.). Presently, the only method for reusing data is to have the PDL maintenance organization to create a duplicate library for an existing payload and then modify/remove all changed/nonapplicable data. For our SSP experiments, our documentation (PIP, annexes) remains the same and has required little if any changes from flight to flight. The only changes made to our experiment series documents over the past several years, was when we made hardware modifications that impacted the performance characteristics of the hardware.*

2. Item Description: PDs are required to resubmit PIRNs for every flight (even while you are on-orbit)

Payload: CPCG

Principal Investigator: Larry Delucas

Recommendation: The PD submits a PIRN with the SYSTEM/ELEMENT AFFECTED AND STAGE EFFECTIVITY filled in to cover the launch through the return flight or through the planned re-flights.

3. Item Description: PDs are required to resubmit COFR for every flight, even if they are just staying on-orbit.

Payload: CPCG

Principal Investigator: Larry Delucas

***Recommendation**: The PD submits one COFR to cover the payload launch, on-orbit and return flights.*

4. Item Description: PDs are required to input and move data.

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: The PDs are required to input data into flights and increments and if the flight moves, then the PDs have to move the data (or yes have it copied and verify the copy worked, some data cannot be copied in PDL such as diagrams, drawings figures). This is inefficient and is subject to human error.

***Recommendation:** Have the PD input data for a payload rather than for a particular flight/increment.*

5. Item Description: Moving Hardware

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: Some of the PD's hardware is moved from one flight to the other. The PD must then go delete this data from one place and add it to another.

***Recommendation:** If the program pre-positions hardware from one flight to the other, they should handle having these items moved within PDL, while keeping the PD in the loop.*

6. Item Description: Moving Payload Item

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: Each time a payload or payload item is moved, a PD must have the PDL team move the appropriate data.

***Recommendation:** Add a capability in PDL enabling the PDs to copy their own data between flights/increments and their associated payload accounts.*

7. Item Description: PDL not keeping up with baseline documentation

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: PDL not keeping up with baseline documentation as well as station decisions. Such as the PDL does not reflect the EXPRESS Rack IDD (SSP 52000-IDD-ERP, Issue B); and thus, we have to submit paper ICDs and PVPs for now and later place into PDL**.** The PDL group has been provided with comments per the POIWG request several times, but appears that no funding is available to even evaluate the PD's comments.

Recommendation: *Provide direction to PDL to revise its system as ISS documentation is revised. Update the PDL blank-book to reflect current design.*

8. Item Description: Payload information not included.

Payload: CPCG

Principal Investigator: Larry Delucas

Discussion: In our experience, payload information was not included for the return flight increment. Thus, when an early transition to the next increment was performed, the system lost the ability for processing the current on-orbit payloads health/status, telemetry, and commands.

Recommendation*: Include payloads in the database for their return flight or next increment for early transition purposes.*

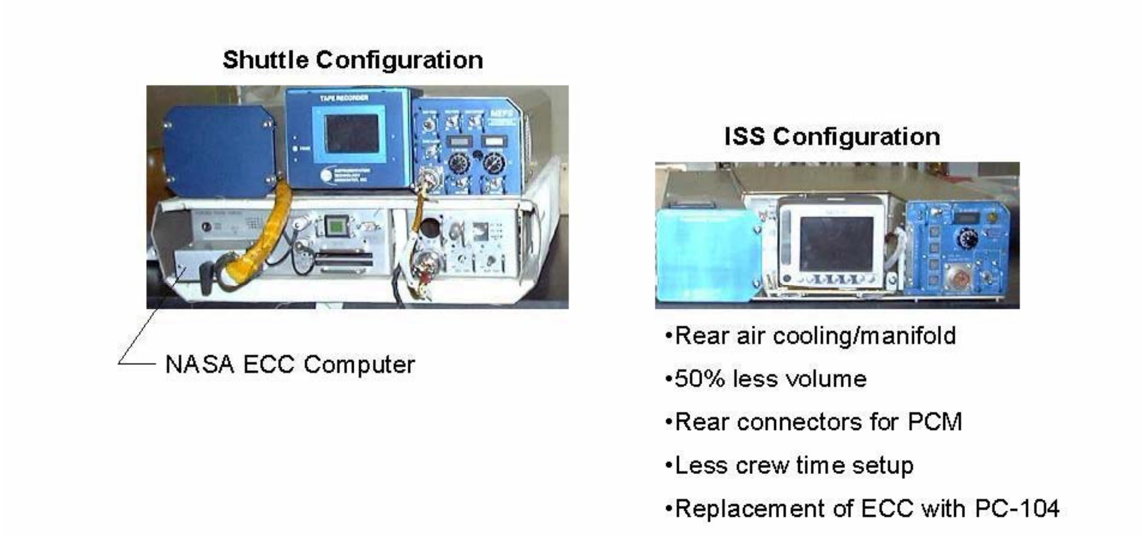
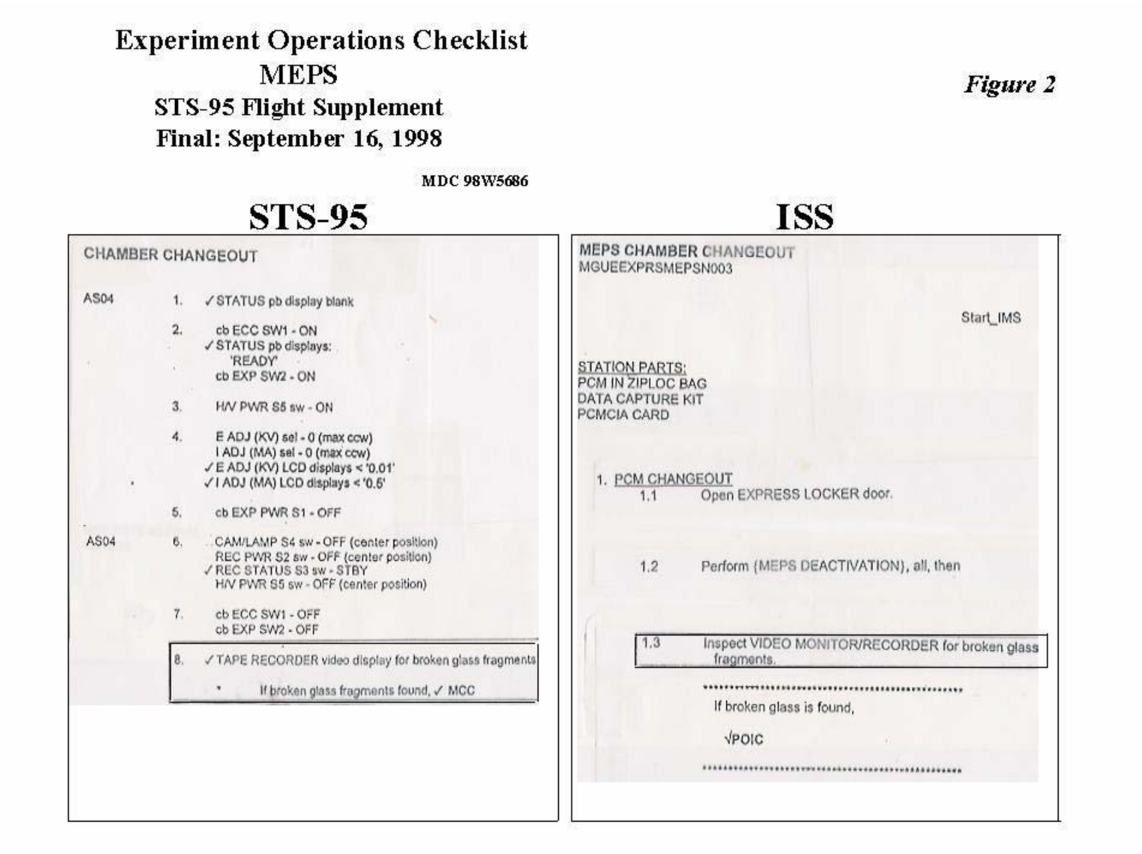


Figure D-1. ***Comparison of Microencapsulation Hardware for Shuttle with Repackaged, Reengineered Hardware for ISS***



Experiment Operations Checklist
MEPS
STS-95 Flight Supplement
Final: September 16, 1998

Figure 2

MDC 98W5686

STS-95

CHAMBER CHANGEOUT

AS04
1. ✓STATUS pb display blank
2. cb ECC SW1 - ON
✓STATUS pb displays: 'READY'
cb EXP SW2 - ON
3. H/V PWR S5 sw - ON
4. E ADJ (KV) sel - 0 (max ccw)
I ADJ (MA) sel - 0 (max ccw)
✓E ADJ (KV) LCD displays < '0.01'
✓I ADJ (MA) LCD displays < '0.5'
5. cb EXP PWR S1 - OFF

AS04
6. CAM/LAMP S4 sw - OFF (center position)
REC PWR S2 sw - OFF (center position)
✓REC STATUS S3 sw - STBY
H/V PWR S5 sw - OFF (center position)
7. cb ECC SW1 - OFF
cb EXP SW2 - OFF
8. ✓TAPE RECORDER video display for broken glass fragments
• If broken glass fragments found, ✓ MCC

ISS

MEPS CHAMBER CHANGEOUT
MGUEEXPRSMEPSN003

Start_IMS

STATION PARTS:
PCM IN ZIPLOC BAG
DATA CAPTURE KIT
PCMCIA CARD

1. PCM CHANGEOUT
1.1 Open EXPRESS LOCKER door.
1.2 Perform {MEPS DEACTIVATION}, all, then
1.3 Inspect VIDEO MONITOR/RECORDER for broken glass fragments.

****
If broken glass is found,
√POIC
****

Figure D-2. ISS PCM Change Out Procedure

Figure 3

SSP 52000-PVP-ERP, Issue A
3/22/00

VERIFICATION REQUIREMENT DEFINITION SHEET

Verification Number	Requirement Title	Verification Method
EL-ER-022	Electrical Bonding of Payload Structures	A and T and I
		Hazard Report Number

Electrical Verification Requirement:

1. The primary payload bond path is through the EXPRESS Rack-to-payload power connector interface. The bond path shall be accomplished by a single 12-AWG wire in the primary power connector capable of carrying a current of 24 A.

   Bonds shall meet the appropriate bond class requirements of paragraph 7.5.1, "Electrical Bonding," and shall have less than or equal to 2.5 milliohms at each junction of the fault bond interface.

   Payloads that will be powered in the Shuttle middeck shall meet the middeck requirement of less than or equal to 0.25 milliohms at each junction of the fault current bond interface. (7.5.1.2.1.1)

2. If necessary, the payload-to-EXPRESS Rack bond strap shall be payload provided and shall be designed to be connected to the EXPRESS Rack structure and payload's ground attachment provisions. This bond shall meet the requirement of paragraph 7.5.1, "Electrical Bonding," and shall have less than or equal to 2.5 milliohms at each junction of the fault current bond interface. (7.5.1.2.1.2)

3. The payload-to-EXPRESS Rack mated surface bond (defined as the payload, adapter plate, or MDL surface that attaches to the EXPRESS Rack back plate) is a removable bond and shall be nickel or nickel plated per SSP 30245 using methods in MIL-C-26074 or D683-29033-1. The maximum resistance between the mated surfaces of the bond connection (connector to mounting base, mounting base to EXPRESS Rack, or when applicable, mounting base to payload) shall be less than or equal to 2.5 milliohms (Class R) at each junction of the fault current bond interface. (7.5.1.2.1.3)

   All the aluminum surfaces used for permanent bonding in the payload shall be originally cleaned to bare metal, then chemically filmed per MIL-C-5541, Class 3 (gold alodine 1200LN9368 or equivalent) or nickel plated using methods in MIL-C-26074.

Description of Verification Method:

1. Verify by inspection that the payload power connector has a 12-AWG wire, capable of carrying a fault current of 24 A, from the ground contact of the connector to the payload chassis.

   Verify by test that the primary connector bond junctions have less than or equal to 2.5 milliohms.

   For payloads that will be powered in the middeck, verify by test that the primary connector bond junctions have less that or equal to 0.25 milliohms at each junction of the fault bond interface.

2. Verify by analysis that the payload-to-EXPRESS Rack bond strap is provided by the payload and is connected between the EXPRESS Rack structure and the payload ground attachment provisions.

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Figure D-3. Basic Bonding Requirement (1 of 2)

Figure 3, continued

SSP 52000-PVP-ERP, Issue A
3/22/00

VERIFICATION REQUIREMENT DEFINITION SHEET (CONTINUED)

Verification Number	Requirement Title	Verification Method
EL-ER-022	Electrical Bonding of Payload Structures	A and T and I
		Hazard Report Number

Description of Verification Method: (Continued)

Verify by test that the bond strap attachment points meet the requirements for a Class R bond and have less than or equal to 2.5 milliohms at each junction.

3. Verify by analysis that the payload-to-EXPRESS Rack mated surface bond (defined as the payload, adapter plate, or MDL surface that attaches to the EXPRESS Rack backplate) is nickel or nickel-plated per SSP 30245 using methods in MIL-C-26074 or D683-29033-1.

   Verify by analysis that all aluminum surfaces used for permanent bonding in the payload are originally cleaned to bare metal, then chemically filmed per MIL-C-5541, Class 3 (gold alodine 1200LN9368 or equivalent) or nickel-plated using methods in MIL-C-26074, Class 4, Grade A.

   Verify by test that the maximum resistance between the mated surfaces of the bond connection (connector to mounting base, mounting base to EXPRESS Rack, or when applicable, mounting base to payload) is less than or equal to 2.5 milliohms at each junction of the fault current bond interface.

Required Verification Data:	*Data Submittal Dates:*
Certificate of Compliance (COC) with the requirement.	L-6 mo

Description of Reverification Requirements:

1. On-orbit subrack PL changeout: Same as the "Required Verification Data" identified above.
2. Payloads remaining on-orbit past the original period of certification of the safety features or inhibits must perform a re-verification of the activities as identified in the "Description of the Verification Method" identified above.

This is the reverification requirement for safety features as per NSTS 18798B, MA2-98-135. It covers not only items that are limited operating life items (i.e., batteries, seals, etc.) but also items such as micro-switches, PRVs, etc., that perform the safety control function for a payload hazard.

Required Reverification Data:	*Data Submittal Dates:*
1. COC 2. Same as "Required Verification Data" identified above.	L-6 mo

Applicable Documents and Notes:

D683-29033-1
MIL-C-5541
MIL-C-26074
MIL-STD-1686
SSP 30245
SSP 52000-IDD-ERP: par 7.5.1.2.1.1, 7.5.1.2.1.2, 7.5.1.2.1.3

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Figure D-3. Basic Bonding Requirement (2 of 2)

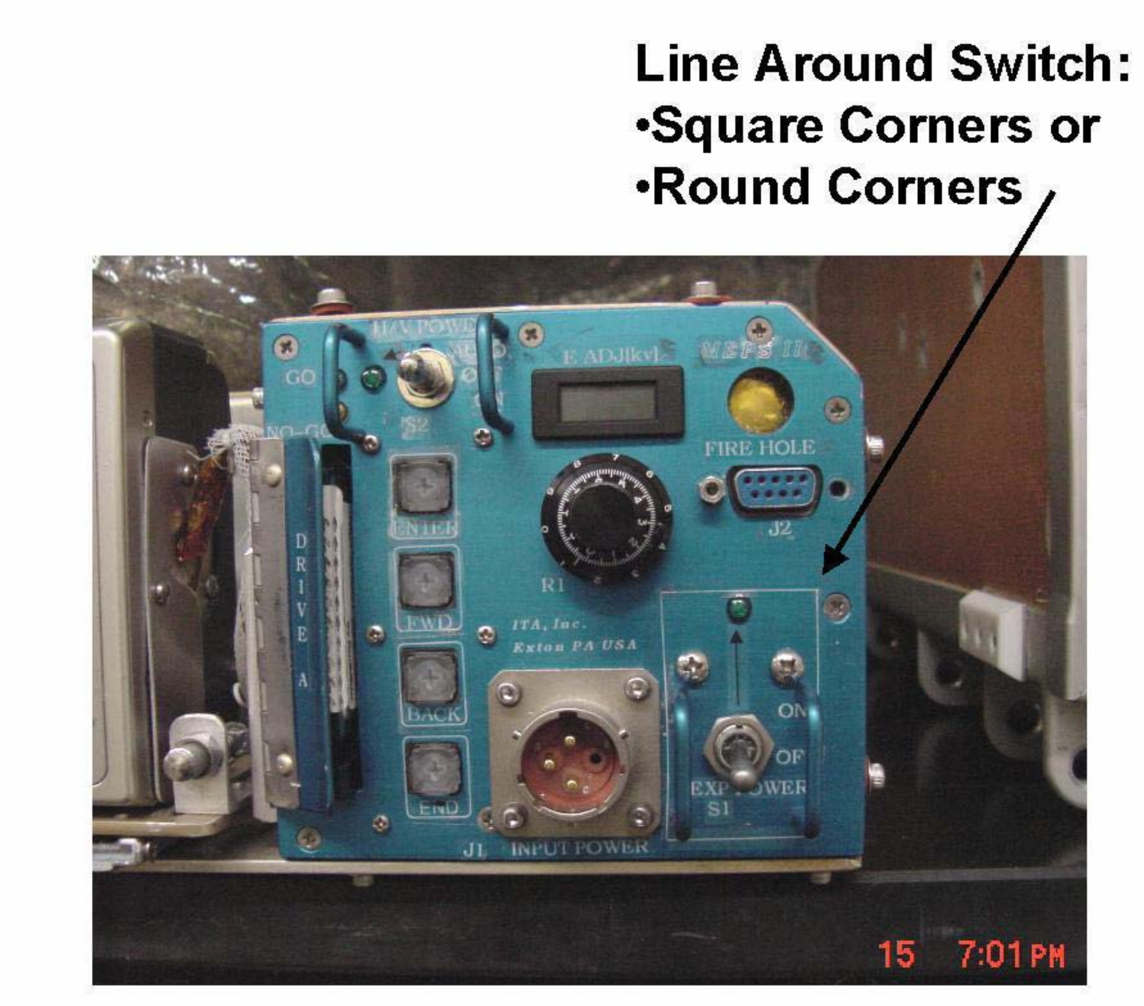


Figure D-4. ISS Hardware—MEPS Faceplate
Example of Unrealistic Requirement That Should Be Changed

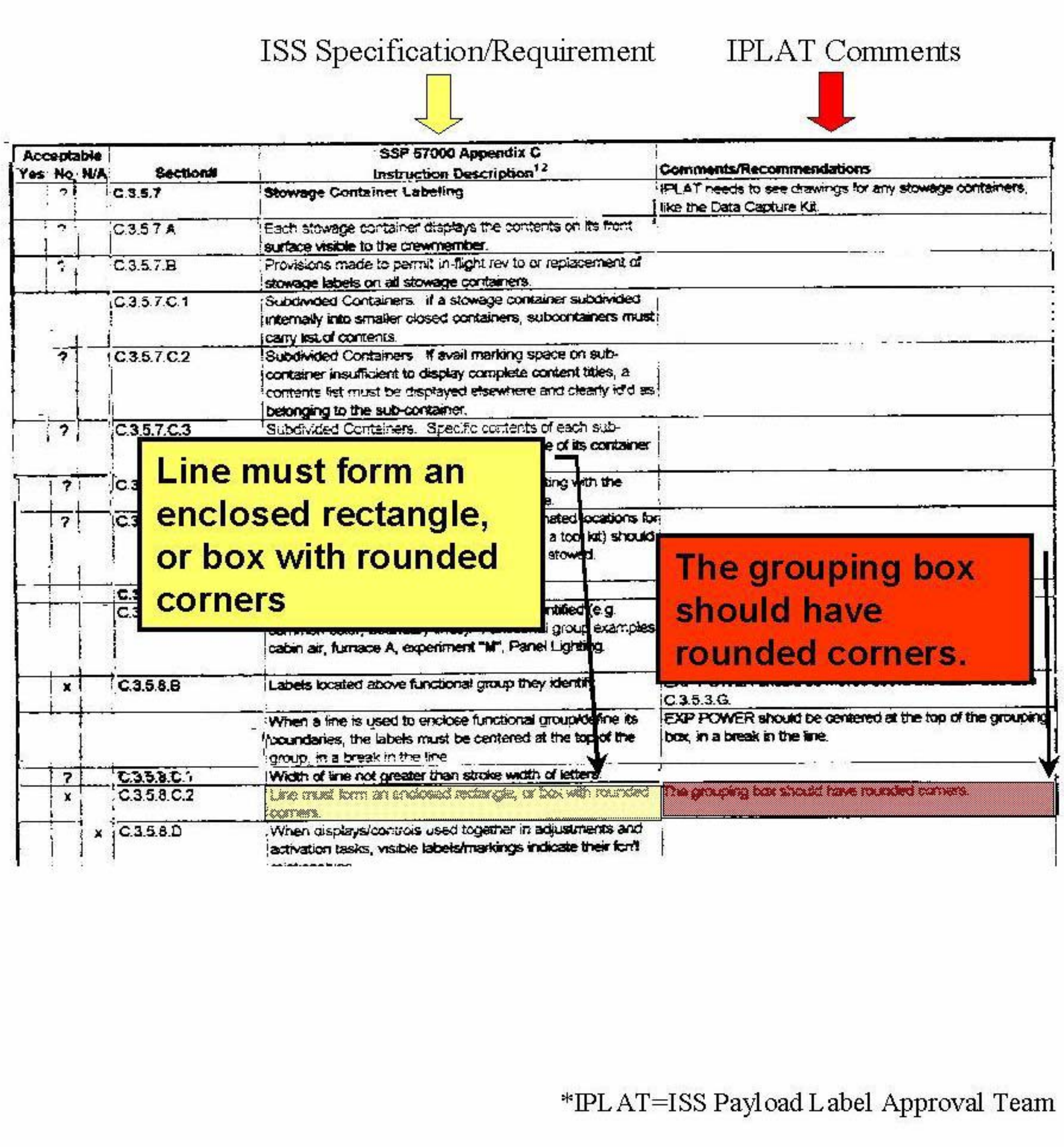
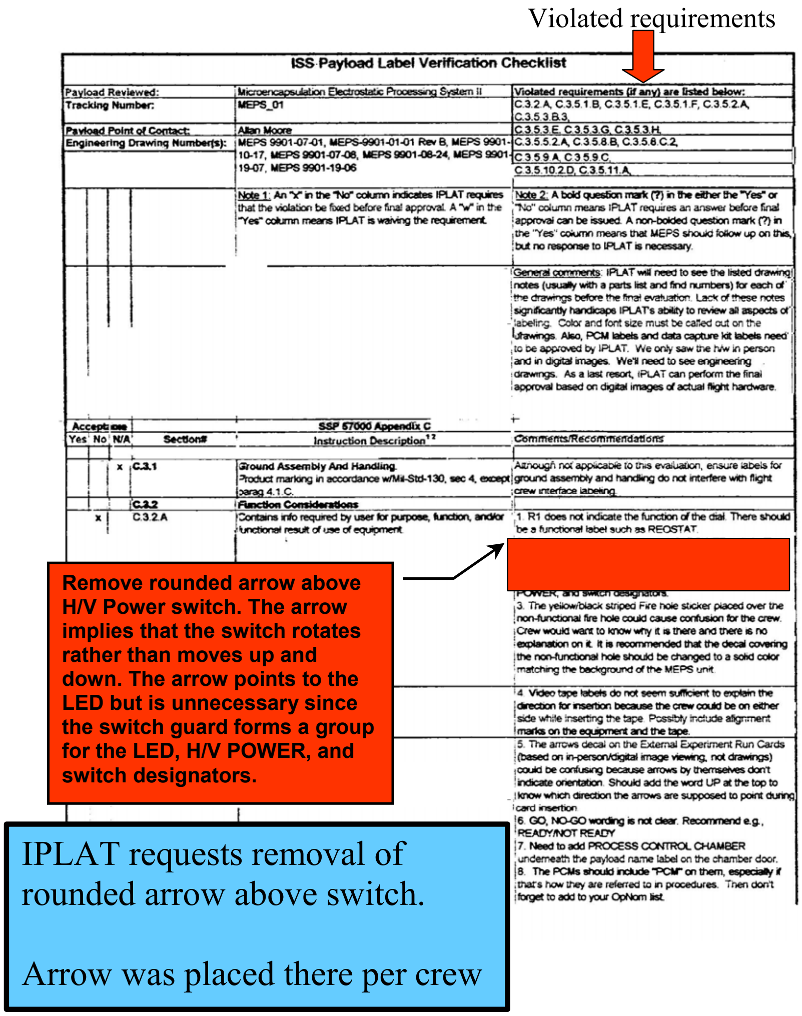


*Figure D-5. Example of ISS MEPS Payload Label Violation from IPLAT**

Figure D-6. Switch With Arrow



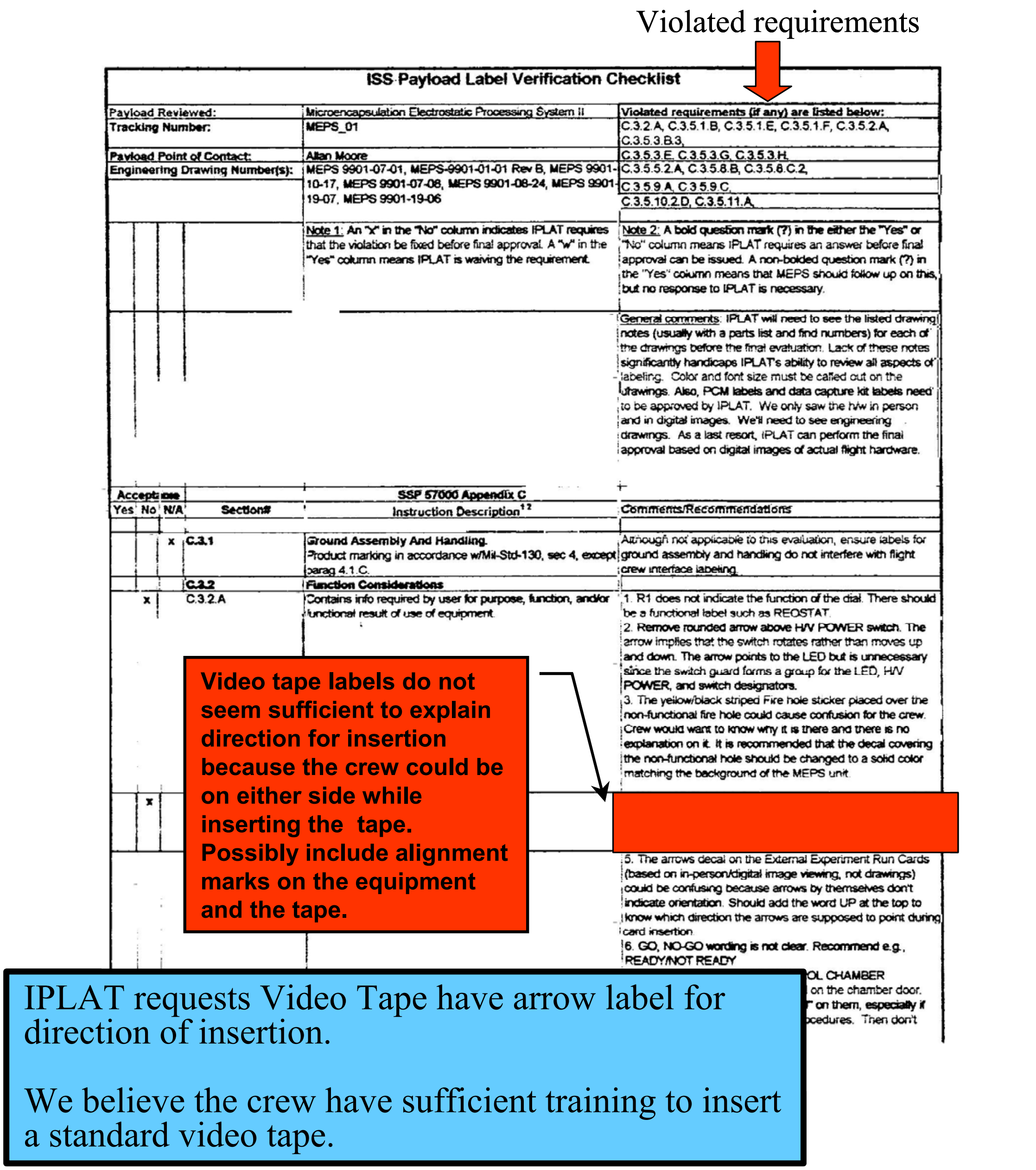
ISS Payload Label Verification Checklist

Payload Reviewed:	Microencapsulation Electrostatic Processing System II	**Violated requirements (if any) are listed below:**
Tracking Number:	MEPS_01	C.3.2.A, C.3.5.1.B, C.3.5.1.E, C.3.5.1.F, C.3.5.2.A, C.3.5.3.B.3,
Payload Point of Contact:	Allan Moore	C.3.5.3.E, C.3.5.3.G, C.3.5.3.H,
Engineering Drawing Number(s):	MEPS 9901-07-01, MEPS-9901-01-01 Rev B, MEPS 9901-10-17, MEPS 9901-07-08, MEPS 9901-08-24, MEPS 9901-19-07, MEPS 9901-19-06	C.3.5.5.2.A, C.3.5.8.B, C.3.5.8.C.2, C.3.5.9.A, C.3.5.9.C, C.3.5.10.2.D, C.3.5.11.A,
	Note 1: An "x" in the "No" column indicates IPLAT requires that the violation be fixed before final approval. A "w" in the "Yes" column means IPLAT is waiving the requirement.	Note 2: A bold question mark (?) in the either the "Yes" or "No" column means IPLAT requires an answer before final approval can be issued. A non-bolded question mark (?) in the "Yes" column means that MEPS should follow up on this, but no response to IPLAT is necessary.
		General comments: IPLAT will need to see the listed drawing notes (usually with a parts list and find numbers) for each of the drawings before the final evaluation. Lack of these notes significantly handicaps IPLAT's ability to review all aspects of labeling. Color and font size must be called out on the drawings. Also, PCM labels and data capture kit labels need to be approved by IPLAT. We only saw the h/w in person and in digital images. We'll need to see engineering drawings. As a last resort, IPLAT can perform the final approval based on digital images of actual flight hardware.

Acceptance Yes	No	N/A	Section#	SSP 57000 Appendix C Instruction Description[1 2]	Comments/Recommendations
		x	**C.3.1**	**Ground Assembly And Handling.** Product marking in accordance w/Mil-Std-130, sec 4, except parag 4.1.C.	Although not applicable to this evaluation, ensure labels for ground assembly and handling do not interfere with flight crew interface labeling.
			C.3.2	**Function Considerations**	
	x		C.3.2.A	Contains info required by user for purpose, function, and/or functional result of use of equipment.	1. R1 does not indicate the function of the dial. There should be a functional label such as REOSTAT. POWER, and switch designators. 3. The yellow/black striped Fire hole sticker placed over the non-functional fire hole could cause confusion for the crew. Crew would want to know why it is there and there is no explanation on it. It is recommended that the decal covering the non-functional hole should be changed to a solid color matching the background of the MEPS unit. 4. Video tape labels do not seem sufficient to explain the direction for insertion because the crew could be on either side while inserting the tape. Possibly include alignment marks on the equipment and the tape. 5. The arrows decal on the External Experiment Run Cards (based on in-person/digital image viewing, not drawings) could be confusing because arrows by themselves don't indicate orientation. Should add the word UP at the top to know which direction the arrows are supposed to point during card insertion. 6. GO, NO-GO wording is not clear. Recommend e.g., READY/NOT READY 7. Need to add PROCESS CONTROL CHAMBER underneath the payload name label on the chamber door. 8. The PCMs should include "PCM" on them, especially if that's how they are referred to in procedures. Then don't forget to add to your OpNom list.

*IPLAT = ISS Payload Label Approval

*Figure D-6a. Example of ISS MEPS Payload Label Violations from IPLAT**



ISS Payload Label Verification Checklist

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Tracking Number:	MEPS_01	C.3.2.A, C.3.5.1.B, C.3.5.1.E, C.3.5.1.F, C.3.5.2.A, C.3.5.3.B.3,
Payload Point of Contact:	Allan Moore	C.3.5.3.E, C.3.5.3.G, C.3.5.3.H,
Engineering Drawing Number(s):	MEPS 9901-07-01, MEPS-9901-01-01 Rev B, MEPS 9901-10-17, MEPS 9901-07-08, MEPS 9901-08-24, MEPS 9901-19-07, MEPS 9901-19-06	C.3.5.5.2.A, C.3.5.8.B, C.3.5.8.C.2, C.3.5.9.A, C.3.5.9.C, C.3.5.10.2.D, C.3.5.11.A

Note 1: An "X" in the "No" column indicates IPLAT requires that the violation be fixed before final approval. A "w" in the "Yes" column means IPLAT is waiving the requirement.

Note 2: A bold question mark (?) in the either the "Yes" or "No" column means IPLAT requires an answer before final approval can be issued. A non-bolded question mark (?) in the "Yes" column means that MEPS should follow up on this, but no response to IPLAT is necessary.

General comments: IPLAT will need to see the listed drawing notes (usually with a parts list and find numbers) for each of the drawings before the final evaluation. Lack of these notes significantly handicaps IPLAT's ability to review all aspects of labeling. Color and font size must be called out on the drawings. Also, PCM labels and data capture kit labels need to be approved by IPLAT. We only saw the h/w in person and in digital images. We'll need to see engineering drawings. As a last resort, IPLAT can perform the final approval based on digital images of actual flight hardware.

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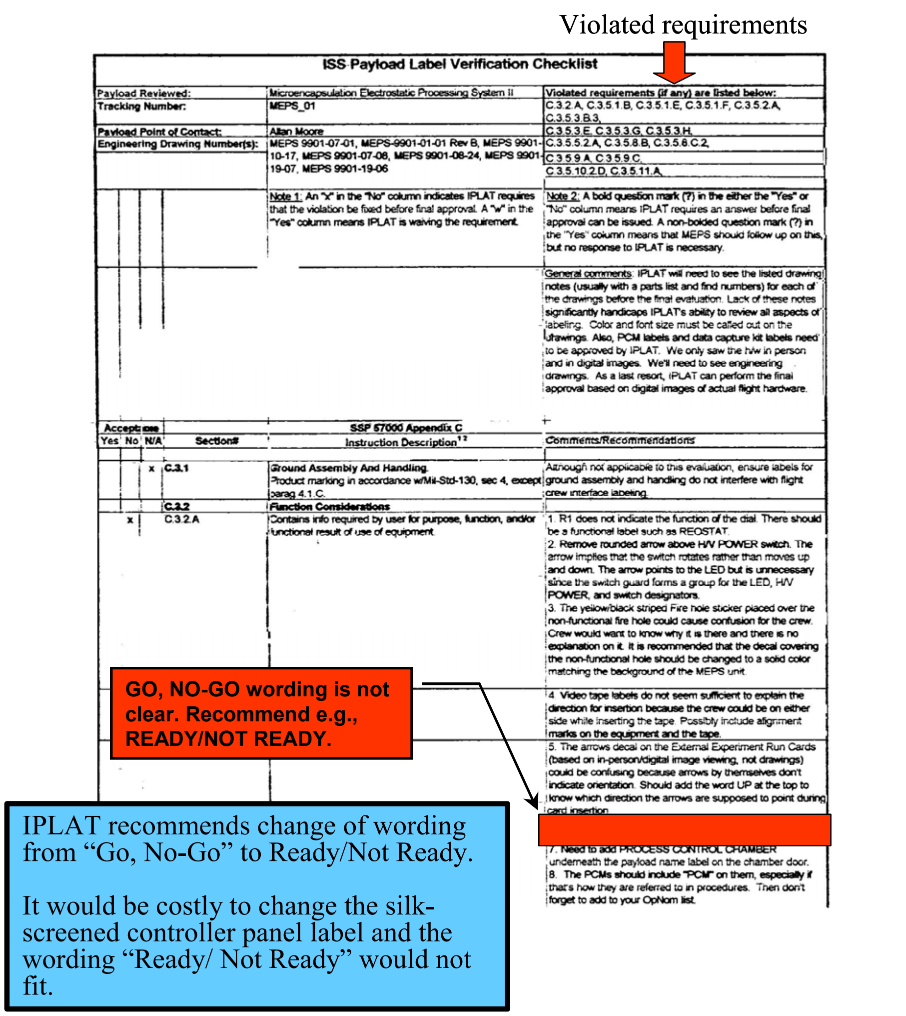
		x	C.3.1	Ground Assembly And Handling. Product marking in accordance w/Mil-Std-130, sec 4, except parag 4.1.C.	Although not applicable to this evaluation, ensure labels for ground assembly and handling do not interfere with flight crew interface labeling.
			C.3.2	Function Considerations	
	x		C.3.2.A	Contains info required by user for purpose, function, and/or functional result of use of equipment.	1. R1 does not indicate the function of the dial. There should be a functional label such as REOSTAT. 2. Remove rounded arrow above H/V POWER switch. The arrow implies that the switch rotates rather than moves up and down. The arrow points to the LED but is unnecessary since the switch guard forms a group for the LED, H/V POWER, and switch designators. 3. The yellow/black striped Fire hole sticker placed over the non-functional fire hole could cause confusion for the crew. Crew would want to know why it is there and there is no explanation on it. It is recommended that the decal covering the non-functional hole should be changed to a solid color matching the background of the MEPS unit.
	x				
					5. The arrows decal on the External Experiment Run Cards (based on in-person/digital image viewing, not drawings) could be confusing because arrows by themselves don't indicate orientation. Should add the word UP at the top to know which direction the arrows are supposed to point during card insertion. 6. GO, NO-GO wording is not clear. Recommend e.g., READY/NOT READY …OL CHAMBER … on the chamber door. …" on them, especially if …ocedures. Then don't

*IPLAT = ISS Payload Label Approval Team

Figure D-7. Example of ISS MEPS Payload Label Violations from IPLAT: Video Tape*

Figure D-8. ISS Hardware - MEPS Faceplate GO/NO-GO Wording on LEDs



ISS Payload Label Verification Checklist

Payload Reviewed:	Microencapsulation Electrostatic Processing System II	**Violated requirements (if any) are listed below:**
Tracking Number:	**MEPS_01**	C.3.2.A, C.3.5.1.B, C.3.5.1.E, C.3.5.1.F, C.3.5.2.A, C.3.5.3.B.3,
Payload Point of Contact:	**Allan Moore**	C.3.5.3.E, C.3.5.3.G, C.3.5.3.H,
Engineering Drawing Number(s):	**MEPS 9901-07-01, MEPS-9901-01-01 Rev B, MEPS 9901-10-17, MEPS 9901-07-08, MEPS 9901-08-24, MEPS 9901-19-07, MEPS 9901-19-06**	C.3.5.5.2.A, C.3.5.8.B, C.3.5.8.C.2, C.3.5.9.A, C.3.5.9.C, C.3.5.10.2.D, C.3.5.11.A,
	Note 1: An "X" in the "No" column indicates IPLAT requires that the violation be fixed before final approval. A "w" in the "Yes" column means IPLAT is waiving the requirement.	Note 2: **A bold question mark (?) in the either the "Yes" or** "No" column means IPLAT requires an answer before final approval can be issued. A non-bolded question mark (?) in the "Yes" column means that MEPS should follow up on this, but no response to IPLAT is necessary.
		General comments: IPLAT will need to see the listed drawing notes (usually with a parts list and find numbers) for each of the drawings before the final evaluation. Lack of these notes significantly handicaps IPLAT's ability to review all aspects of labeling. Color and font size must be called out on the drawings. Also, PCM labels and data capture kit labels need to be approved by IPLAT. We only saw the h/w in person and in digital images. We'll need to see engineering drawings. As a last resort, IPLAT can perform the final approval based on digital images of actual flight hardware.

Acceptance Yes	No	N/A	Section#	SSP 57000 Appendix C Instruction Description[1,2]	Comments/Recommendations
		x	**C.3.1**	**Ground Assembly And Handling.** Product marking in accordance w/Mil-Std-130, sec 4, except parag 4.1.C.	Although not applicable to this evaluation, ensure labels for ground assembly and handling do not interfere with flight crew interface labeling.
			C.3.2	**Function Considerations**	
	x		C.3.2.A	Contains info required by user for purpose, function, and/or functional result of use of equipment.	1. R1 does not indicate the function of the dial. There should be a functional label such as REOSTAT. 2. Remove rounded arrow above H/V POWER switch. The arrow implies that the switch rotates rather than moves up and down. The arrow points to the LED but is unnecessary since the switch guard forms a group for the LED, H/V POWER, and switch designators. 3. The yellow/black striped Fire hole sticker placed over the non-functional fire hole could cause confusion for the crew. Crew would want to know why it is there and there is no explanation on it. It is recommended that the decal covering the non-functional hole should be changed to a solid color matching the background of the MEPS unit.
					4. Video tape labels do not seem sufficient to explain the direction for insertion because the crew could be on either side while inserting the tape. Possibly include alignment marks on the equipment and the tape.
					5. The arrows decal on the External Experiment Run Cards (based on in-person/digital image viewing, not drawings) could be confusing because arrows by themselves don't indicate orientation. Should add the word UP at the top to know which direction the arrows are supposed to point during card insertion.
					7. Need to add PROCESS CONTROL CHAMBER underneath the payload name label on the chamber door. 8. The PCMs should include "PCM" on them, especially if that's how they are referred to in procedures. Then don't forget to add to your OpNom list.

*IPLAT = ISS Payload Label Approval Team

Figure D-8a. Example of ISS MEPS Payload Label Violations from IPLAT: GO/NO-GO Wording on Control Panel*

Figure 9

VERIFICATION REQUIREMENT DEFINITION SHEET

Verification Number	Requirement Title	Verification Method
HF-ER-014	Color	I
Human Factors Verification Requirement:		Hazard Report Number
Payloads shall select interior colors in accordance with the requirements of SSP 52000-IDD-ERP, Table 12-I. (12.5.1)		
Description of Verification Method: An inspection/evaluation of the as-built hardware (PD equipment item/decal/placard/label) shall be performed to verify that colors are per SSP 52000-IDD-ERP, Table 12-I.		
Required Verification Data: Certificate of Compliance (COC) with the requirement.		*Data Submittal Dates:* L-6 mo
Description of Reverification Requirements: No reverification required.		
Required Reverification Data: None Required.		*Data Submittal Dates:* N/A
Applicable Documents and Notes: FED-STD-595 SSP 52000-IDD-ERP: par 12.5.1 Note: Delivery date assumes 30 days prior to turnover to KSC, and PD hardware must be turned over to KSC at L-5 months.		

Figure D-9. ISS Color Requirement (1 of 2)

Figure 9, continued

12.4.6.2 Self-Supporting Covers

All access covers that are not completely removable shall be self-supporting in the open position.

12.5 IDENTIFICATION LABELING

EXPRESS Rack payloads, loose equipment, stowage trays, consumables, ORUs, crew accessible connectors and cables, switches, indicators, and controls shall be labeled. Labels are markings of any form (including Inventory Management System (IMS) bar codes) such as decals and placards, which can be adhered, "silk screened," engraved, or otherwise applied directly onto the hardware. Appendix E provides instructions for label and decal design and approval.

12.5.1 Color

Payloads shall select colors in accordance with the requirements of Table 12-I.

TABLE 12-I EXPRESS RACK PAYLOAD COLOR REQUIREMENTS

HARDWARE DESCRIPTION	COLOR	FINISH	SPECIFICATION NUMBER PER FED-STD-595B
Rack Front Aisle Extensions	Off-White	Semigloss	27722
Port, Starboard, Ceiling, or Floor Rack Faceplates	Off-White	Semigloss	27722
Port, Starboard, Ceiling, or Floor Rack Utility Panel Closeouts	Off-White	Semigloss	27722
Deck Rack Faceplates	Off-White	Semigloss	27722
Stowage Trays	Off-White	Semigloss	27722
Stowage Tray Handle Straps (any location)	Blue Material	Semigloss	25102 or equivalent
Equipment Panel Text Characters	Black	Lusterless	37038

12.5.2 Fluid Connector Pressure/Flow Indicators

All non-brazed or non-welded gas and liquid lines that will be opened/disconnected on orbit shall be provided with a positive indication of the presence of gas pressure/fluid flow to verify that the line is passive before opening/disconnecting connectors (visual indicator, etc.). Any liquid or gas lines equipped with QDs which are designed to be operated under pressure shall not be required to be fitted with pressure/flow indicators.

Figure D-9. ISS Color Requirement (2 of 2)

Figure 10

SSP 52000-PVP-ERP, Issue A
3/22/00

VERIFICATION REQUIREMENT DEFINITION SHEET

Verification Number	Requirement Title	Verification Method
HF-ER-020	Toggle Switches	I
		Hazard Report Number

Human Factors Verification Requirement:

Dimensions for a standard toggle switch shall conform to Figure 12-13 of SSP 52000-IDD-ERP, "Toggle Switches." (12.6.4)

Description of Verification Method:

An inspection/evaluation of the as-built hardware (toggle switches) shall be performed to verify that it meets the dimensions of Figure 12-13 of SSP 52000-IDD-ERP.

Required Verification Data:	*Data Submittal Dates:*
Certificate of Compliance (COC) with the requirement.	L-6 mo

Description of Reverification Requirements:

1. Same as "Verification Requirement" above.
2. Payloads remaining on-orbit past the original period of certification of the safety features or inhibits must perform a re-verification of the activities as identified in the "Description of the Verification Method" identified above.

This is the reverification requirement for safety features as per NSTS 18798B, MA2-98-135. It covers not only items that are limited operating life items (i.e., batteries, seals, etc.) but also items such as micro-switches, PRVs, etc., that perform the safety control function for a payload hazard.

Required Reverification Data:	*Data Submittal Dates:*
Same as "Required Verification Data" identified above.	L-6 mo

Applicable Documents and Notes:

SSP 52000-IDD-ERP: par 12.6.4

Note: Delivery date assumes 30 days prior to turnover to KSC, and PD hardware must be turned over to KSC at L-5 months.

A-207

Figure D-10. Toggle Switch Requirement (1 of 3)

Figure 10, continued

B. Intermediate-Torque Valves - Valves requiring between 10 and 20 in-lb (1 and 2 N-m) for operation are classified as "intermediate torque" valves and shall be provided with a "central pivot" type handle, 2.25 in (5.5 cm) or greater in diameter, or a "lever end pivot-type" handle, 3 in (7.5 cm) or greater in length.

C. High-Torque Valves - Valves requiring 20 in-lb (2 N-m) or more for operation are classified as "high-torque" valves and shall be provided "lever type" handles 3 in (7.5 cm) or greater in length.

D. Handle Dimensions - Valve handles shall adhere to the clearances and dimensions illustrated in Figures 12-11, Valve Handle-Central Pivot Type and 12-12, Valve Handle-Lever Type.

E. Rotary Valve Controls - Rotary valve controls shall open the valve with a counter-clockwise motion.

12.6.4 Toggle Switches

Dimensions for a standard toggle switch shall conform to the values presented in Figure 12-13, Toggle Switches.

12.6.5 Stowage and Equipment Drawers/Trays

A. All latches, handles, and operating mechanisms shall be designed to be latched/unlatched and opened/closed with one hand by the 95th percentile American male to the 5th percentile female.

B. The design of latches shall be such that their status (locked/unlocked) can be determined through visual inspection.

12.6.6 Audio Devices (Displays)

A. The design of audio devices (displays) and circuits shall protect against false alarms.

B. All audio devices (displays) shall be equipped with circuit test devices or other means of operability testing.

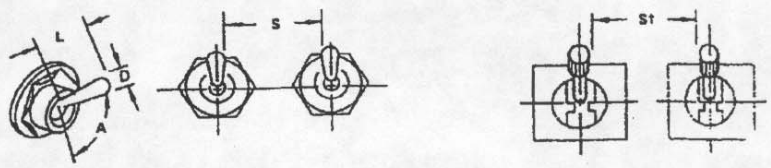
C. An interlocked, manual disable shall be provided if there is any failure mode which can result in a sustained activation of an audio device (display).

Figure D-10. Toggle Switch Requirement (2 of 3)

Feb 04 02 06:03p ita 6103638569 p.8

Figure 10, continued

SSP 52000-IDD-ERP, Issue B
12/13/00



	Dimensions		Resistance	
	L Arm length	D Control tip	Small switch	Large switch
Minimum	13 mm (1/2 in)	3mm (1/8 in)	2.8 N (10 oz)	2.8 N (10 oz)
Maximum	50 mm (2 in)	25 mm (1 in)	4.5 N (16 oz)	11 N (40 oz)

	Displacement between positions A	
	2 position	3 position
Minimum	30°	17°
Maximum	80°	40°
Desired		25°

	Separation S			
	Single finger operation	†	Single finger sequential operation	Simultaneous operation by different fingers
Minimum	19 mm (3/4 in)	25 mm (1 in)	13 mm (1/2 in)	16 mm (5/8 in)
Optimum	50 mm (2 in)	50 mm (2 in)	25 mm (1 in)	19 mm (3/4 in)

† Using a lever lock toggle switch

MSIS-239

Reference: 2, page 93

FIGURE 12-13 TOGGLE SWITCHES

12-18

Figure D-10. Toggle Switch Requirement (3 of 3)

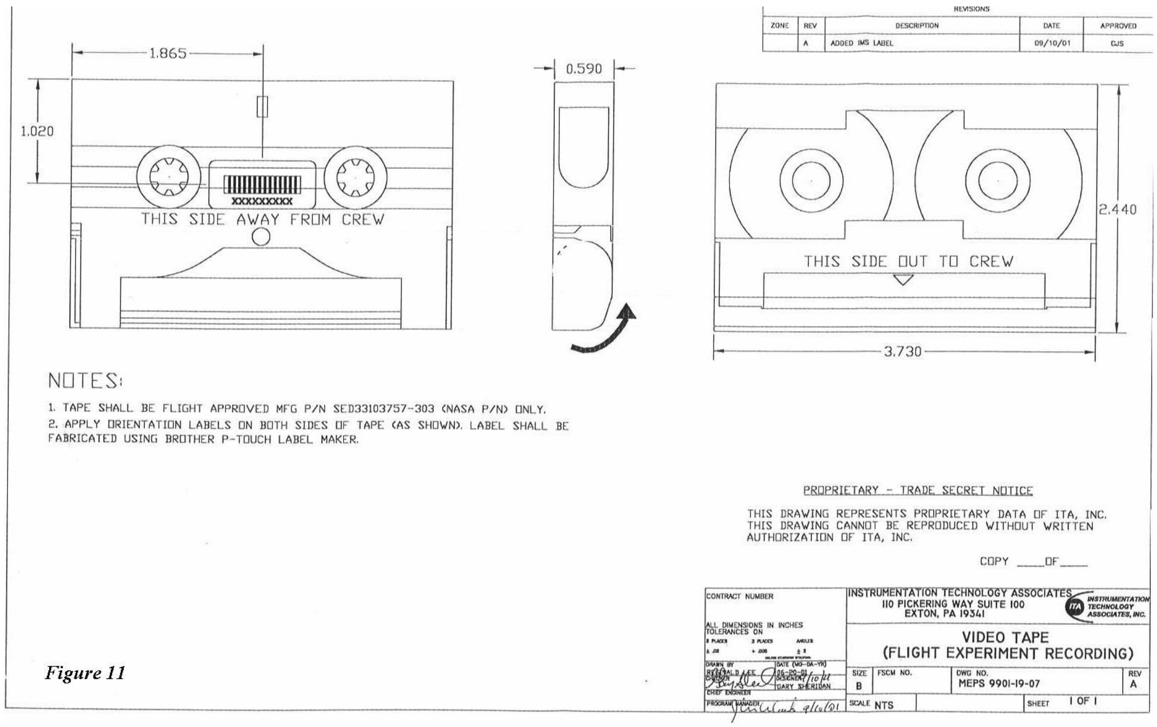


Figure D-11. Signed Off Drawing of Videotape Cassette

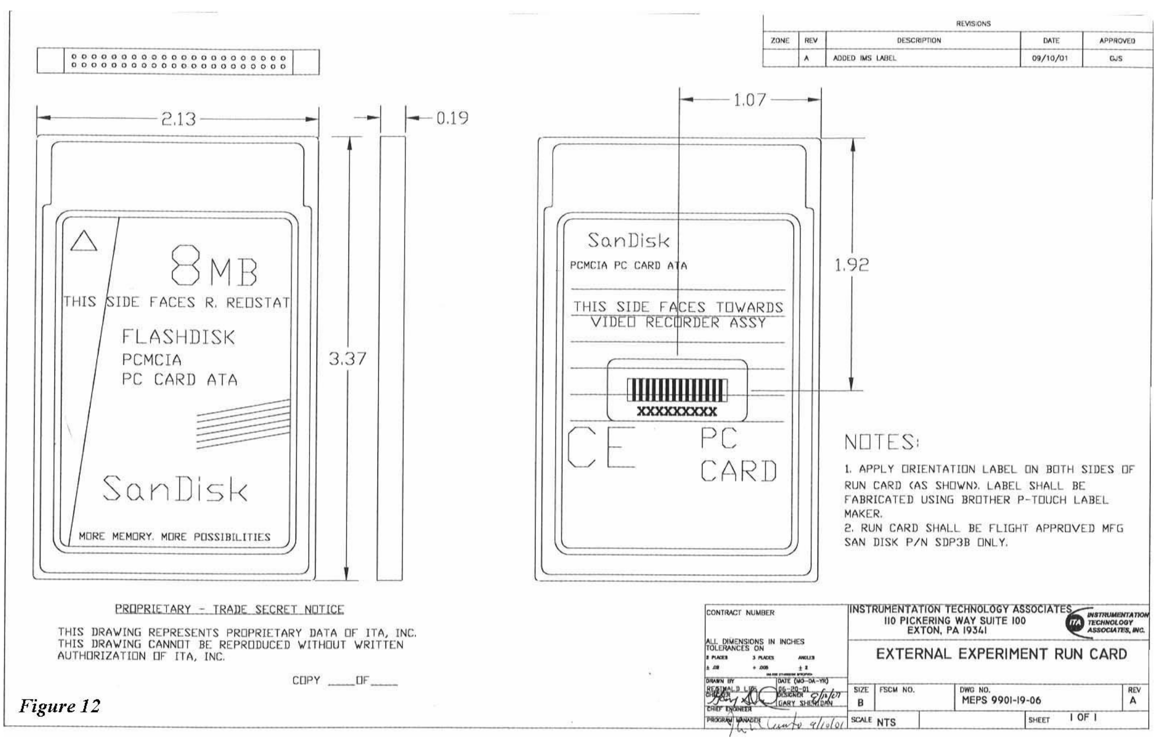


Figure D-12. Signed Off Drawing of PCMCIA Card

Appendix E
ISS Crew Time and the IMCE Report

Although the principal focus of POCASS is on ways to "save money" within Payload Operations activities, it will be a fruitless effort if there is no ability left to do meaningful research on the ISS. At the current baseline level of 20 hours/week of manned payload operations, U.S. manned science opportunities have all but disappeared. Additional threats to payload crew time include the reduced work-day hours (8 to 6 1/2), division of time between Russian, International and U.S. crew persons, and division of time among science, technology and commercial endeavors,. A focus entirely on automated telescience, controlled by ground-based PI Teams, might be all that is practical. Significant Payload Operations cost savings might be possible in this minimal scenario, although restarting manned payload activities at some future date would be very difficult and expensive, owing to loss of cadre expertise.

The recent IMCE (Young Report) holds promise of a different operations concept with substantially more crew time available. To restate several of the points in their Executive Summary (with additional explanation within the body of the Report), they "find":

- "There are opportunities to maximize research on the core station program with modest cost impact" (their stress).
- "The U.S. Core Complete configuration (three person crew) as an end-state will not achieve the unique research potential of the ISS".

And "required action":

- "Additional crew time must be allocated to support the highest priority research."

In reaching these conclusions, the Young Committee was briefed by Mr. Tommy Holloway, the NASA Director of the ISS Program. He provided several "Interim Options to Increase Crew Complement." He notes that with Soyuz missions overlapping by one month (instead of 10 to 14 days), an additional 350 hours of crew time are available for payload operations, twice per year. He also notes that if "Extended Duration Orbiter" visits are planned, docked for 16 days (instead of 7 to 9 days), an additional 500 hours for payload operations are available, twice per year, at a modest cost. If both of these independent options are combined, the available payload operations time increases from (20 hrs/week x 52) = 1040 hours to (1040 + 1700) = 2740 hours/year, a very significant increase at minimal cost.

In fact, the opportunity is substantially greater than that outlined above. Consider the following relatively minor adjustments to the Young Report recommendations.

1. NASA described a 16-day docked mission to ISS, consistent with that demonstrated on the18-day flight of STS-80 in 1996. However, STS-80 required that all Orbiter systems be fully powered for almost the full mission, depleting the stored cryogens for electricity production more rapidly than required for a docked mission at the ISS. If the Orbiter is "powered down" to a quiescent state after docking at the ISS, earlier Rockwell studies over a decade ago show power generation can be extended to 28-days or more. Mr. Arnold Aldrich, a past Space Shuttle Program Director, described this option in Space

News, April 30, 2001, pg. 14. With a docked period of approximately 28 days, manned payload operations should be extended to about 1000 hours, twice per year. Total ISS manned payload operations would now approximate 1040 (3 person crew) + 700 (Soyuz overlap) + 2,000 (EDO) = 3,740 hrs/yr.

2. Some have raised an objection to having the Orbiter Commander (CDR) return for a landing after some 30-days in space, although it has already been demonstrated as acceptable up to 18-days. It seems reasonable to work into this gradually, increasing from 20-, to 25-, to 30-days in space. Alternatively, the EDO mission can be shifted so that it immediately precedes the arrival of a new Soyuz, with slight overlap. A "fresh" U.S. CDR can be brought up in Soyuz to return the Orbiter to a landing. And finally, the Orbiter has always had a fully automatic landing capability (other than manual gear extension), although the crews have always opted for manual control in the final phase of landing.

3. Other enhancements are possible as well, including reduction of Orbiter power levels to the minimum cryo consumption rate, set by heat absorption into the cryo tanks. More expensive (and therefore deferred for now) would be modest electrical power transfer of only a few kw from ISS to Orbiter, enabling visit durations of several months.

4. Of benefit to science operations would be a concentration on infrastructure tasks during the high crew availability of the Orbiter visit as recommended in the Young Report, in return for more than 20 hours/week of payload operations during the 3-crew phases. Also, an agreement with the Russians to bring up two American and/or International crew persons on Soyuz flights, in return for two Russian crew persons on the EDO missions, would spread out the crew availability for all national interests more evenly across each increment.

5. Another benefit to crew availability would be to use a 5-month increment spacing, rather than 6-month increments as suggested in the Young report. This provides a larger fraction of the total time with larger numbers of crew, but at a corresponding increase in flight rate.

Finally turning to cost savings, as the Young Report notes, a substantial reduction of flight rate, from 6 or 7 flights/year to only 4 or 5 flights/year, is the only way to make major cost reductions. All of the above options are consistent with this, requiring only two EDO flights/year for crew exchange. Another 2 or 3 Orbiter flights may be required for Station maintenance, but the Young Report notes possible savings of as much as $669 million/year. Some of this saving should be expended for additional payload hardware and operations, again consistent with their recommendations.

Abbreviations and Acronyms

ADF	Avian Development Facility
A/G	air-to-ground
AOS	acquisition of signal
ARC	Ames Research Center
ARIS	Active Rack Isolation System
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
BAA	Business Area Architecture
BANDIT	B/W integration timeliner
BNL	Brookhaven National Laboratories
BOE	basis of estimate
BPS	Bio-mass Production System
BRP	Biological Research Project
BSTC	biotechnology specimen temperature
BT	biotechnology
BTR	biotechnology research
C&DH	communications and data handling
CAM	centrifuge accommodations module
CCSDS	Consultative Committee for Space Data Standards
CD	compact disc
CEO	chief executive officer
CIR	combustion integrated rack
Code OZ	Utilization Office of the ISS Program Office
Code U	Office of Biological and Physical Research
COFR	certification of flight readiness
COR	communicator outage recorder
COTS	commercial off-the-shelf
CPO	command P/L MDM officer
CPS	Crew Planning System
CR	change request
CRV	crew rescue vehicle
CSA	Canadian Space Agency
CSC	Computer Sciences Corporation
CSOC	Consolidated Space Operations Contract
CY	calendar year
DBMS	Database Management System
DDS	Data Distribution Service
DEC	Digital Equipment Corporation
DMC	data management coordinator
DNS	domain name service
DRM	design reference mission
EDO	extended duration orbiter
EHS	Enhanced HOSC System
ERIS	EHS Remote Interface System

ESA	European Space Agency
ETOV	earth-to-orbit vehicle
EXPRESS	EXpedite the Processing of Experiments to Space Station
FB-Cell	fundamental biology-cell culture research
FC	fluids and combustion
FIR	fluid integrated rack
FTE	full-time equivalent
FTP	file transfer protocol
FY	fiscal year
GRC	Glenn Research Center
GSFC	Goddard Space Flight Center
GSP	ground support personnel
GST	ground support team
HCOR	high-rate communications outage
HOSC	Huntsville Operations Support Center
HR	human research
HRF	Human Research Facility
HRFM	high-rate frame multiplexer
HVoDS	HOSC Voice Distribution System
IBM	International Business Machines
ICE	ISS Characterization Experiment
IDRD	Integrated Data Requirements Document
IF	interface
IMCE	ISS Management and Cost Evaluation
IP	international partner
ISS	International Space Station
ISSPO	International Space Station Program Office
IT	information technology
IViDS	Internet Video Distribution System
IVoDS	Internet Voice Distribution System
JEM	Japanese Experiment Module
JOIP	Joint Operations Integration Panel
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
LOE	level of effort
LSE	laboratory support equipment
LVLH	local vertical local horizontal
mb/s	megabits per second
MCC	Mission Control Center
MCOR	multipurpose communications outage recorder
MDL	middeck locker
MDM	multiplexer-demultiplexer
MIR	Russian Space Station
MOBIS	Management, Organizational, and Business Improvement Services
MOU	Memorandum of Understanding

MPV	manual procedures viewer
MS	material science
MSFC	Marshall Space Flight Center
MSG	microgravity science glovebox
NAC	NASA Advisory Council
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NDE	non-real time development environment
NDL	near real time data log
NISN	NASA Integrated Services Network
NMS	Network Management System
NRT	near real time
NTP	network time protocol
OC	operations controller
OCMS	Operations Control Management System
OCR	operations change request
OMB	Office of Management and Budget
OOS	on-orbit summary
Opns	operations
OTE	operations test equipment
PAI	payload analytical integration
PARC	payload activity requirements collection
PBS	President's Budget Submission
PC	personal computer
PCB	Payload Control Board
PCC	Partner Control Centers
PCG	protein crystal growth
PD	payload developer
PDL	Payload Data Library
PDRF	payload data request form
PDRP	Payload Data Review Panel
PDRT	Payload Display Review Team
PDSS	Payload Data Services System
PHANTOM	photo & TV operations manager
PI	principal investigator
PIMS	Payload Information Management System
PIRNs	program interface revision notices
PL	payload
PLSS	Payload Support Systems
PLUM	payload utilization modeler
POC	point of contact
POCAAS	Payload Operations Concepts and Architecture Study
POD	payload operations director
PODF	payload operations data file
POH	Payload Operations Handbook
POIC	Payload Operations Integration Center

POIF	Payload Operations Integration Function
POIWG	Payload Operations Interface Working Group
PPM	payload planning manager
PPS	Payload Planning System
PPSE	P/L planning/scheduling engineer
PRO1	payload rack officer 1
PRO2	payload rack officer 2
PSE	payload systems engineer
PTC	Payload Training Complex
PUFF	The Effect of EVA and Long-Term Exposure to Microgravity on Pulmonary Function
RFP	Request for Proposal
ROSE	request-oriented scheduling engine
RPI	remote principal investigator
RPOs	Research Program Offices
RPWG	Research Planning Working Group
RSA	Russian Space Agency
RT	real time
SAMS	Space Acceleration Measurement System
SAT	science, aeronautics, and technology
SFOC	Space Flight Operations Contract
SGI	Silicon Graphics Incorporated
SLOC	source lines of code
SMAC	system monitor & control
SOC	shuttle operations coordinator
SOMO	Space Operations Management Office
SOW	scope of work
SPD	Space Product Development
SSCC	Space Station Control Center
SSP	Space Shuttle Program
SSTF	Space Station Training Facility
STP	short term plan
STS	Space Transportation System
SW	software
TBE	Teledyne Brown Engineering
TCO	timeline change officer
TCP/IP	transfer control protocol/interface protocol
TDRSS	Tracking and Data Relay Satellite System
TDS	Time Distribution System
TMM	timeline maintenance manager
TSC	Telescience Support Center
	Training Support Contract
UMS	Utilization Mission Support
UPN	universal project number
USOC	United States Operations Center
VBSP	video baseband signal processor

WAN	wide area network
WISARD	weekly data systems/resources
WORF	Window Observational Research Facility
WSC	White Sands Center
XPOP	X-axis perpendicular to orbit plane
ZCG-FU	Zeolite Crystal Growth